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CF105

PROTECTION AGAINST ICE

UNLIMITED

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CF-105 PROTECTION AGAINST ICE

UNCLASSIFIED

CF-105 PROTECTION AGAINST ICE

1.0 INTRODUCTION

Encounters with ice which endanger the life of the aircraft and crew, or seriously interfere with operations, occur very seldom. To avoid penalising the aircraft performance it is most necessary to ensure that equipment carried is really required.

1.0.1 AEROFOIL SURFACES

Early in the design stages of the CF-105, it was suspected that de-icing of the aerofoil surfaces could be dispensed with. Considering the time likely to be spent in icing conditions the maximum conceivable ice accretion did not have enough weight to interfere seriously with the ability of the aircraft to climb out of an icing layer, nor did the drag of the accretion interfere with the ability to accelerate to a speed at which the kinetic temperature rise would melt any ice formation. There remained, however, the question of stability and control. Pictures were obtained from the N.A.C.A. of bad ice accretions on a swept aerofoil similar to the CF-105 wing. Tests were carried out in the wind tunnel, at Ottawa, on a CF-105 wing with similar simulated ice accretions and the aerodynamic characteristics of the wing were measured. No serious effects on stability or control could be detected from the tunnel test results. In order to save weight and complication, de-icing of the aerofoil surfaces has been omitted from the CF-105.

1.0.2 WINDSCREEN AND CANOPY WINDOWS

Because of requirements for clear vision the pilot's windscreen and canopy windows are anti-iced. The navigator's window is not. An electro-thermal method is used. The system is automatic and no pilot's controls are provided.

1.0.3 ENGINE INTAKES

Pieces of ice which have formed on the engine intake ramp or lips, and which have become detached, will enter the engine at very nearly the air velocity in the intake. In this way the CF-105 differs from most other aircraft where pieces of ice would have a short distance to travel, after becoming detached, before entering the engine. The high kinetic energy of such pieces of ice would mean that they are capable of doing considerable damage to compressor blades, if the pieces of ice are large.

The various factors influencing intake design dictated that a hot air anti-icing system was impractical. An electro-thermal system was therefore adopted. Because of the prohibitive power requirements of an anti-icing system, a cyclic de-icing system was adopted. It aims at shedding acceptably small thicknesses of ice for the engine to accept them without damage. The system is automatic and no pilot's controls or indicators are provided.

1.0.4 RADOME

For the aircraft to function as an effective fighting vehicle, the performance of the fire control system must be close to one hundred percent in all conditions. For this reason an alcohol anti-icing and de-icing system is fitted. The system is automatic and no pilot's controls are provided.

1.1 WINDSCREEN AND CANOPY WINDOWS

The canopy windows and the windscreen are heated to ensure clear vision. This includes heating to prevent misting and frosting up as well as to prevent ice formation on the outside surface.

1.1.1 TRANSPARENCIES

These transparencies are heated by a conducting layer on the inside surface of the outside sheet of glass. Power is continuously available for this purpose, both on the ground and in flight, and is not contingent on being in icing conditions.

Development work has been carried out on test CF-105 windscreens and it has been found possible to grade the resistivity of the conducting film in such a way that only a single positive bus and a single negative bus are required on either the windscreen or the canopy window. The areas heated are shown on Fig. 1.1

1.1.2 POWER INPUT

Raw 115v. 3 phase power is taken from the main aircraft bus and converted to single phase. Tappings on the transformer give the correct output voltage for the transparencies fitted.

1.1.3 TEMPERATURE CONTROL

The power input to the transparencies is regulated by a temperature controller which works on resistance type sensing elements embedded in the glass. The controller is set to regulate the power input in such a way as to give temperatures of 110°F at the sensing elements.

1.2 ENGINE INTAKES

The engine intake lips and ramps are protected by a cyclic de-icing system, the object of which is to ensure that the pieces of ice entering the engine intakes are acceptably small to be swallowed without the engines being damaged.

1.2.1 DESIGN PHILOSOPHY

Design of the engine intake de-icing system was based on the premise that the simultaneous existence of two emergency conditions was sufficiently unlikely that the occurrence could be dismissed from consideration. The emergencies taken into account were (1) the existence of icing conditions, and (2) the failure of an alternator. By postulating that these two events

1.2.1 DESIGN PHILOSOPHY (Continued)

will never occur simultaneously, we can take power for de-icing the port intake from the port alternator and power from the starboard alternator to de-ice the starboard intake. In this way there is no need to duplicate power supplies for intake de-icing and thus we save weight.

1.2.2 POWER AVAILABLE

Preliminary studies of the anticipated rate of ice accretion were made, as were assumptions on the size of the pieces of ice which could be consumed by the engine without damage. From this data the power requirements of the system were calculated.

This work gave an order of magnitude of the power requirements. The data on which the calculations were made was, however, of questionable validity, and flight in the CF-105 would appear to be the only way in which sound data could be acquired. However, the order of magnitude obtained was obviously not too wide of the mark.

From this work, power of 10 kvA. total per intake was made available to the system. All subsequent design work was based on this quantity.

1.2.3 REGIONS DE-ICED

After discussions with the N.A.C.A. it was decided to de-ice the complete surface of the intake ramp back to the "hump" and the inside surface of the lips for a distance of approximately 12 inches around the surface from the stagnation point. Fig. 1.2.1 shows the extent of the protectors.

1.2.4 PRINCIPLES OF OPERATION

1.2.4.1 SYSTEM FOR ONE ENGINE INTAKE

Initially, let us consider one engine intake only. An ice detector is located in the engine intake duct. This unit acts as a rate of icing meter by generating an electrical pulse each time approximately .020 inches of ice builds up on the detecting probe. On receipt of the first pulse from the detector, the icing controller switches on the parting and dividing strips. These strips separate shedding areas, of which there are ten, and ensure clean removal of ice when heat is applied to an area. Before commencing to shed ice it is well to wait until a reasonable thickness of ice has been built up so that aerodynamic forces will remove it cleanly. The icing controller, therefore, waits until it has received a predetermined number of pulses from the detector prior to commencing a shedding cycle.

1.2.4.1 SYSTEM FOR ONE ENGINE INTAKE (Continued)

Having received the requisite number of pulses, the controller then regulates the power distributor to apply power to each of the ten shedding areas in turn. Fig. 1.2.4 shows the location of the shedding areas.

In continuous icing conditions, the ice detector will have been generating pulses throughout the shedding cycle. If sufficient pulses have been received at the icing controller, a second shedding cycle will commence immediately after completion of the first cycle, and this process will continue while pulses arrive at the icing controller with sufficient rapidity.

If, at the completion of a shedding cycle, insufficient pulses have been received for a second cycle to commence, the icing controller will wait for the right number of pulses to arrive before initiating a further shedding cycle.

Should the total number of pulses required to initiate a cycle not arrive, the controller will initiate a further shedding cycle on completion of the "Over-Hang-Time" after the arrival of the last pulse. Provided no further signal arrives from the ice detector during the shedding cycle, the system will then shut down.

1.2.4.2 SYSTEM FOR BOTH ENGINE INTAKES

There is one power distributor and one ice detector per engine. However, one icing controller serves both intakes. Fig. 1.2.2 is a block diagram illustrating the system.

When only one engine is running the icing controller will serve only that side of the aircraft.

When both engines are running, the ice detector on the port side becomes the master detector and the icing controller receives signals from that detector only. The controller will, however, regulate both power distributors to simultaneously control both de-icing systems.

1.2.4.3 THE ICE DETECTORS (Fig. 1.2.3)

The ice detector consists of two probes and a pressure switch. Both probes have small holes drilled in their leading and trailing surfaces. These probes are piped to opposite sides of the pressure switch. One probe is continuously heated, while the other is normally unheated.

1.2.4.3 THE ICE DETECTORS (Fig. 1.2.3) (Continued)

When ice forms on the unheated probe, pressure falls inside the probe and the pressure switch makes contact A pulse is delivered to the icing controller and at the same time power is applied to the iced up probe. As soon as the probe de-ices, pressure rises in that probe thus breaking the pressure switch contact and removing de-icing power from the probe which is once again ready to detect the presence of icing conditions.

1.2.4.4 THE CONTROLLER

The controller is the heart of the intake de-icing system. On receipt of the first icing signal it energises relay(s) which apply power to the parting and dividing strips. It then commences counting icing pulses until a sufficient number arrive to commence a shedding cycle. Because the efficiency of catch of the intake lips and ramp is unknown, the required number of pulses to give optimum shedding is also unknown. The controller has, therefore, been made capable of adjustment for the number of pulses required to initiate shedding.

Once having initiated shedding the controller generates pulses at predetermined intervals to cause the power distributors to transfer the load from one shedding area to another. Because of the unknowns involved in the system, the unit is capable of adjustment of the interval between pulses.

The unit also contains a time delay which, when no icing pulses are received during the time setting of the delay, causes a final shedding cycle to be carried out prior to system shut down. This time delay is capable of adjustment.

1.2.4.5 THE POWER DISTRIBUTOR

This unit is a stepping contactor carrying the shedding power from the bus bars to the ice protectors. On receipt of signals from the controller, this unit will switch power from shedding area to shedding area.

1.2.4.6 THE ICE PROTECTORS

Each intake ramp and lip will be covered by six ice protectors. These protectors, or boots, are of neoprene rubber construction of .065" thickness. One protector covers the tip while one other protector covers the remainder of the ramp. The other four protectors cover the intake lips.

1.2.4.6 THE ICE PROTECTORS (Continued)

The intake ramp is split into six shedding regions of equal area. The ramp tip and the boundary layer suction slot are continuously heated, as are dividing strips between shedding areas. The shedding areas are vertical strips and it is intended to commence shedding at the forward end of the ramp and to systematically work towards the rear.

The protectors for the lips extend around the inside and the outside of the intake for a distance of about 18 inches. A parting strip of ½" width runs around the stagnation region and is continuously heated. The portion of the protectors outside the intake duct is unheated. The heated region inside the duct extends for about 12 inches around the surface from the parting strip. The lips are divided into four shedding areas which are separated by dividing strips. Parting and dividing strips are heated at 20 watts/sq.inch and shedding areas at 12 watts/sq.inch.

1.2.4.7 OVERHEAT PROTECTION

An overheat switch is located in each shedding area. Any tendency for a shedding area to overheat will result in power being switched off. A similar overheat switch will be located at the critical part of the dividing strips. Fig. 1.2.5 shows a section through a protector and an overheat switch.

1.2.4.8 DESCRIPTION OF THE INSTALLATION

Fig. 1.2.1 shows an engine intake.

1.2.4.8.1 EQUIPMENT

With the exception of cabling, overheat switches and the protectors themselves, all components of an intake de-icing system are located together, just behind the protectors on the upper surface of aircraft, and just inboard of the intake duct.

This equipment is accessible through a large screwed panel. Cables from the protectors arrive at this area via conduits and connect to terminal strips. On the port side of the aircraft the controller, distributor, detector, overload protection and relays are all located together. A similar installation exists on the starboard side of the aircraft, except that the controller is missing.

1.2.4.8 DESCRIPTION OF THE INSTALLATION (Continued)

1.2.4.8.2 PROTECTORS

The protectors are of neoprene rubber and are supplied by the Goodrich Rubber Company. The intake structure is recessed to the thickness of the protectors which are attached by an adhesive. Except at the tip of the ramp and at the boundary layer bleed, the surface finish of the protectors will be the normal rubber finish. High erosion is, however, expected at the ramp tip, and in this region the boot is covered by a .005" layer of steel foil. A similar layer of steel foil covers the boundary layer bleed where it is used to conduct heat small distances across the surface to portions where heating elements cannot be located due to the hole configuration.

Six boots cover the protected area. When fitting boots to an intake, trimming the boots to obtain a good fit is permissible. Trim lines are clearly marked. Gaps between boots may be filled with a filling compound and "buffed up" to give a smooth finish.

1.2.4.8.3 OVERHEAT SWITCHES

Overheat protection is provided by small bi-metallic switches located on the aft side of the boots. These switches operate to energise a power cut-off relay when any one of them overheats. These switches are attached to the boot by a rubber cup and leads from the switch are carried within the thickness of the boot to the region in which the equipment is mounted.

Switches can be replaced without replacing the boot by peeling the boot back and removing the covering cup.

1.3 RADOME

In the early design stages of the CF-105, consideration was given to hot air and pneumatic type anti-icing and de-icing systems for the radome. We discovered that radomes of similar shape to the CF-105 were proving extremely difficult to make, with acceptable electrical properties, even when solid laminates were used. Hence we discarded the idea of hot air and pneumatic systems as imposing impossible problems for the radome manufacturers. An alcohol system was, therefore, adopted.

In this system, alcohol is sprayed from a distributor at the base of the nose boom. By suitable arrangement of the discharge nozzles, this alcohol mixes

1.3 RADOME (Continued)

with the intercepted water and ice on the radome to depress its freezing point such that it flows rearwards to a point where it no longer interferes with the radar.

1.3.1 PRINCIPLES OF OPERATION

Fig. 1.3.1 is a diagram of the Radome De-Icing System. The alcohol is contained in a tank of approximately 2.75 gallons capacity. Air at 10-12 psi. on the surface of the liquid tends to drive it towards the distributor in the nose boom. In conditions where ice is not forming, its path is blocked by a three-way valve. This valve is operated by a time delay relay which gets its information from an ice detector.

When ice is detected, the time delay relay energises the three-way valve to allow alcohol to flow to the distributor for approximately one second. During this period, approximately .04 gallons are dispensed. At the same time, it operates a shut-off valve allowing pressure air to flow to the three-way valve where it is temporarily blocked. After one second, the time delay relay de-energises the three-way valve so that the alcohol flow is shut off, but the pressure air can now flow to the distributor. For a period of nine seconds this air purges the supply line of alcohol so that at the end of the period no radar interference remains. Provided no further icing signals are received from the detector, the shut-off valve is de-energised and de-icing is complete. The time delay relay has, however, the capacity to store an icing signal. Should a signal arrive during the cycle it will be stored and, at the end of one cycle, another will begin until such time as no further signals arrive, when the system will shut down.

The air supply comes from the Low Pressure Pneumatics System at pressures of from 18 to 85 psi. A pressure reducing valve in the line cuts this pressure to 10-12 psi. before delivering it to the tank. A relief valve is fitted to blow off at 14 psi. in the event of such a reducing valve failure. A non-return valve in the supply line will prevent a back flow of alcohol into the low pressure pneumatics system.

1.3.2 INSTALLATION

1.3.2.1 ALCOHOL TANK

The tank is situated on the upper side of the nose structure, just forward of the windscreen. It is filled from the top after removal of the filler cap. A gauze filter in the filler neck will remove foreign matter and act as a level gauge. When full, the liquid level will be just above the bottom of the filter. The liquid used is denatured ethyl alcohol.

1.3.2 INSTALLATION (Continued)

1.3.2.2 ICE DETECTOR

The Ice Detector is situated on the underside of the nose structure just forward of the nose wheel well. It is removed by undoing four screws on the outside of the aircraft and withdrawing it. This item will be supplied by P.S.C. Applied Research.

1.3.2.3 TIME DELAY RELAY

The Time Delay Relay is situated on the upper side of the nose structure and is accessible through the large hinged panel on the starboard side of the aircraft. The unit will be supplied by Hayden.

1.3.2.4 AIR SUPPLY

The Pressure Reducing Valve, Non Return Valve, Pressure Relief Valve, Shut-Off Valve and Three-Way Valve are all located adjacent to the Time Delay Relay.

The Pressure Reducing Valve will be supplied by Surface Combustion, and is presently a standard item.

The Non-Return Valve is a standard A.N. part.

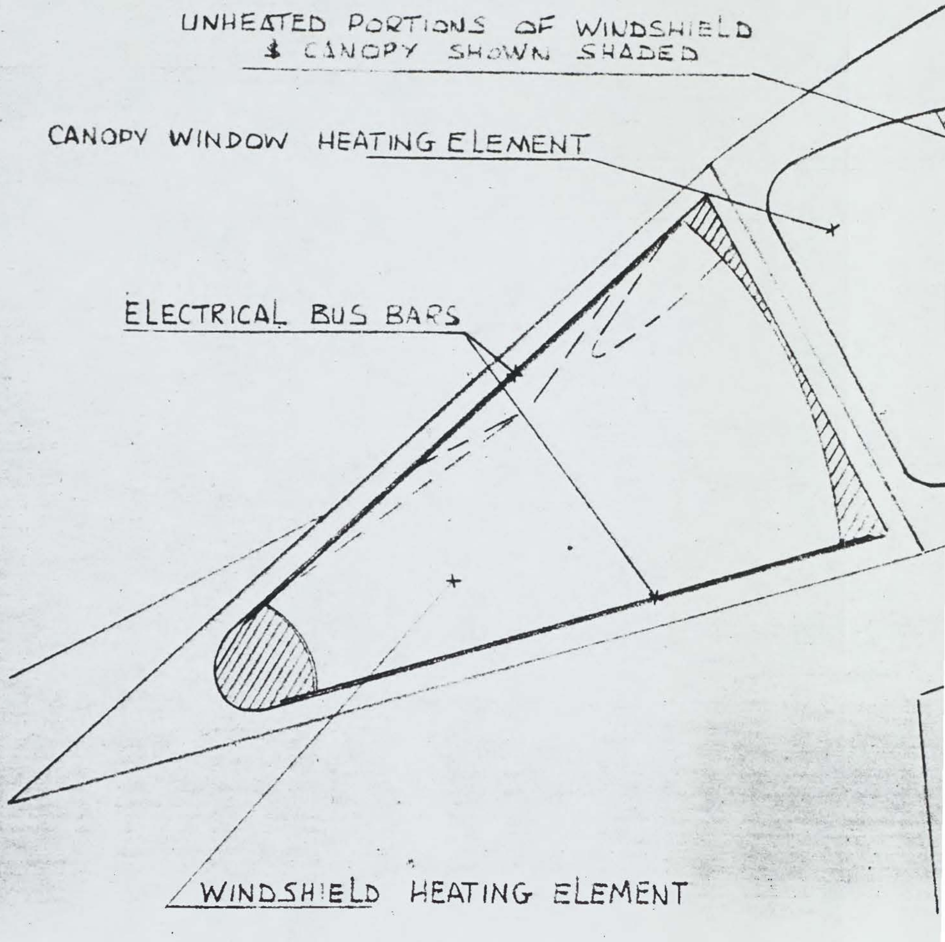
The Pressure Relief Valve will be supplied by Aero Supply.

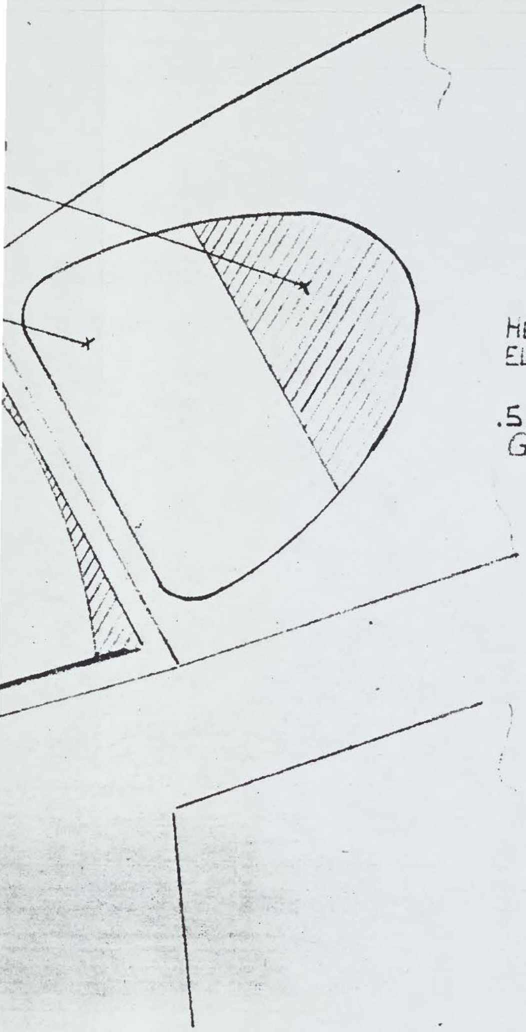
The Shut-Off Valve is a standard item and will be supplied by the Eckel Valve Company.

The Three-Way Valve is to Avrocan Specification No. E221, and will be supplied by Aero Eckel.

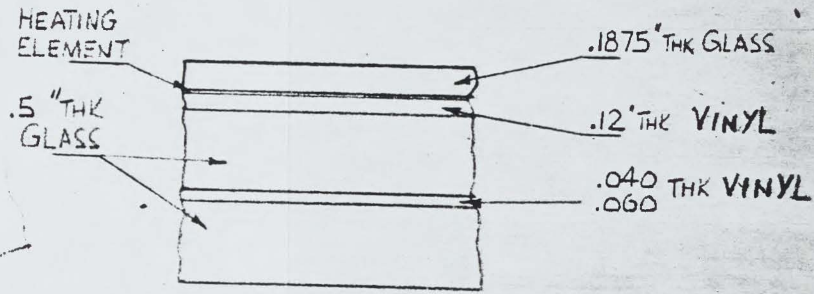
1.3.2.5 DISTRIBUTOR

Piping from the three-way valve to the distributor will be fabricated from plastic Temflex 105 tubing. The distributor consists of a hollow ring around the base of the nose boom to which the plastic pipe is attached. 16 holes of .020" diameter, drilled to point rearwards at an angle of 45° form the distributing nozzles. Fig. 1.3.2 is a section through the distributor.


UNHEATED PORTIONS OF WINDSHIELD
$ CANOPY SHOWN SHADED
CANOPY WINDOW HEATING ELEMENT
ELECTRICAL BUS BARS
WINDSHIELD HEATING ELEMENT

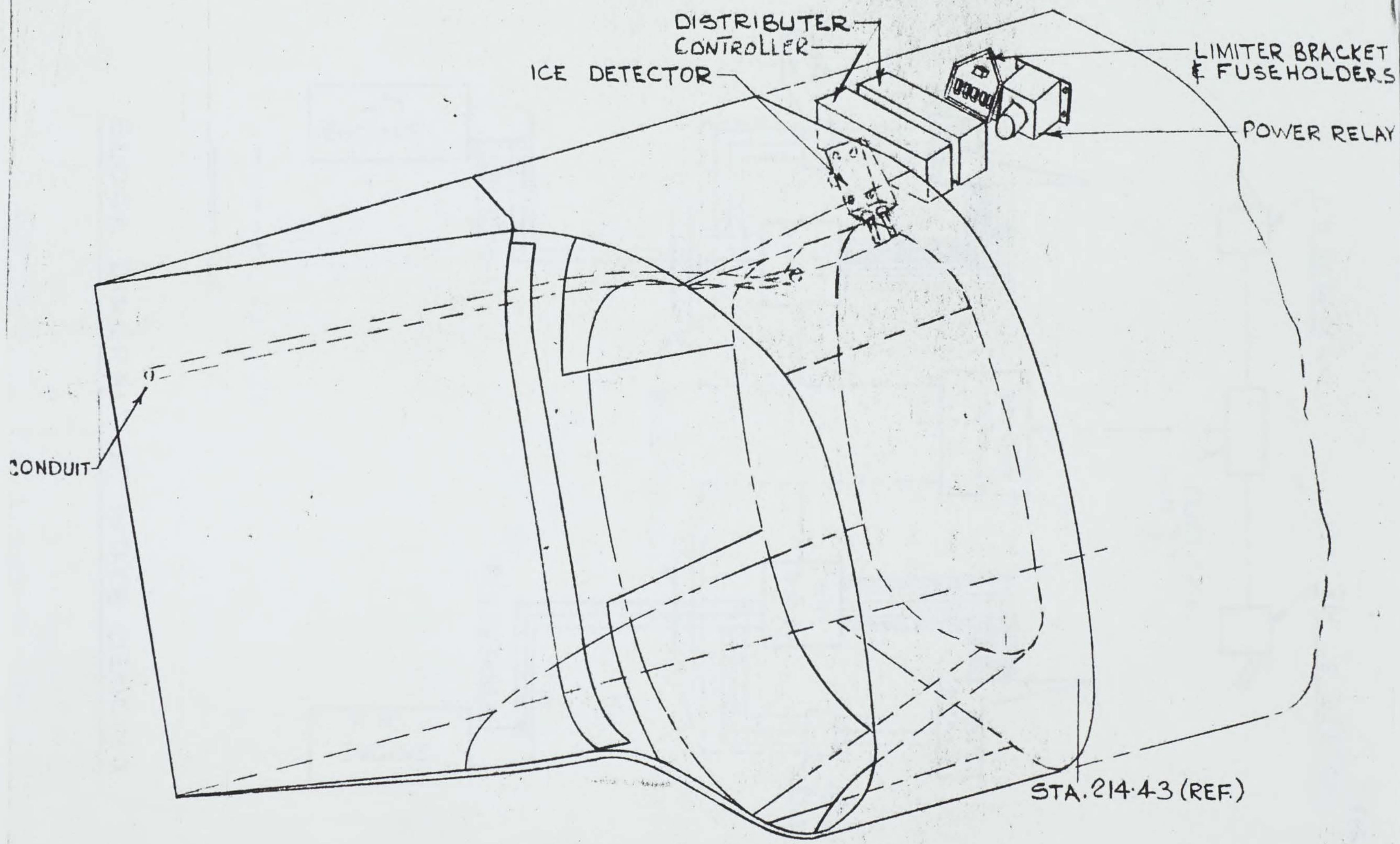


POWER INPUT FOR HEATED AREAS OF WINDSCREEN IS AS FOLLOWS :- 4.3 WATTS PER SQ INCH
THIS IS CALCULATED ON A HEAT FLOW OF 2100 BTU PER HOUR PER SQ ft



SECTION THRU LAMINATED WINDSCREEN

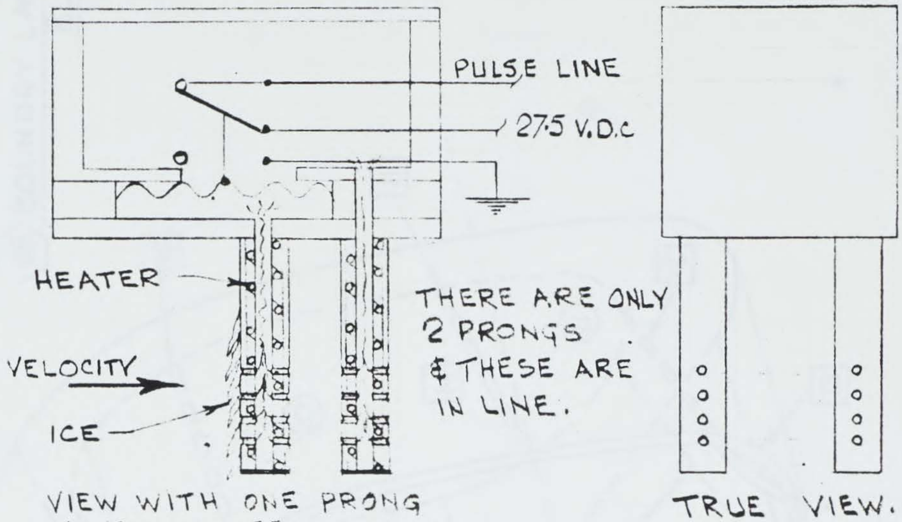
WIND SCREEN & CANOPY DE-ICING



DE-ICING EQUIPMENT

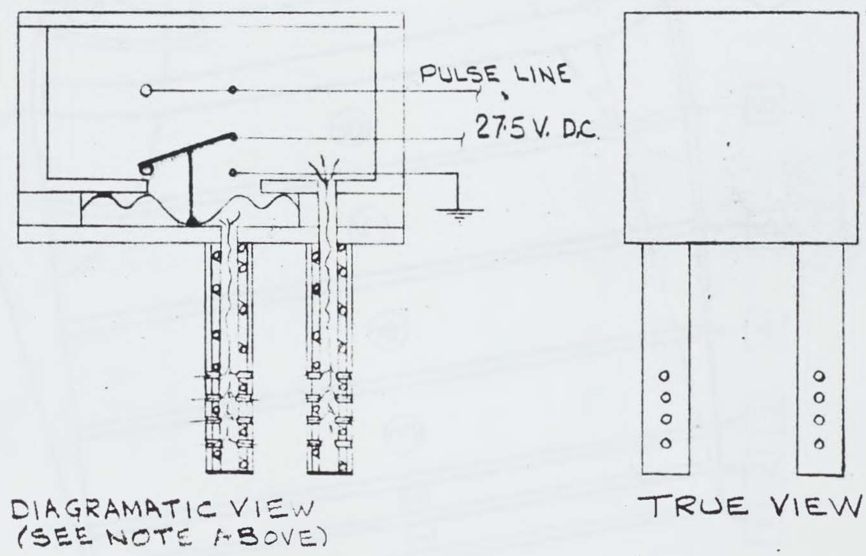
FIG. 1.2.1

FIG 1.2.3.



VIEW WITH ONE PRONG MOVED OUT FROM CORRECT POSITION TO SHOW FUNCTION OF SWITCH

ICE DETECTOR IN ICED CONDITION

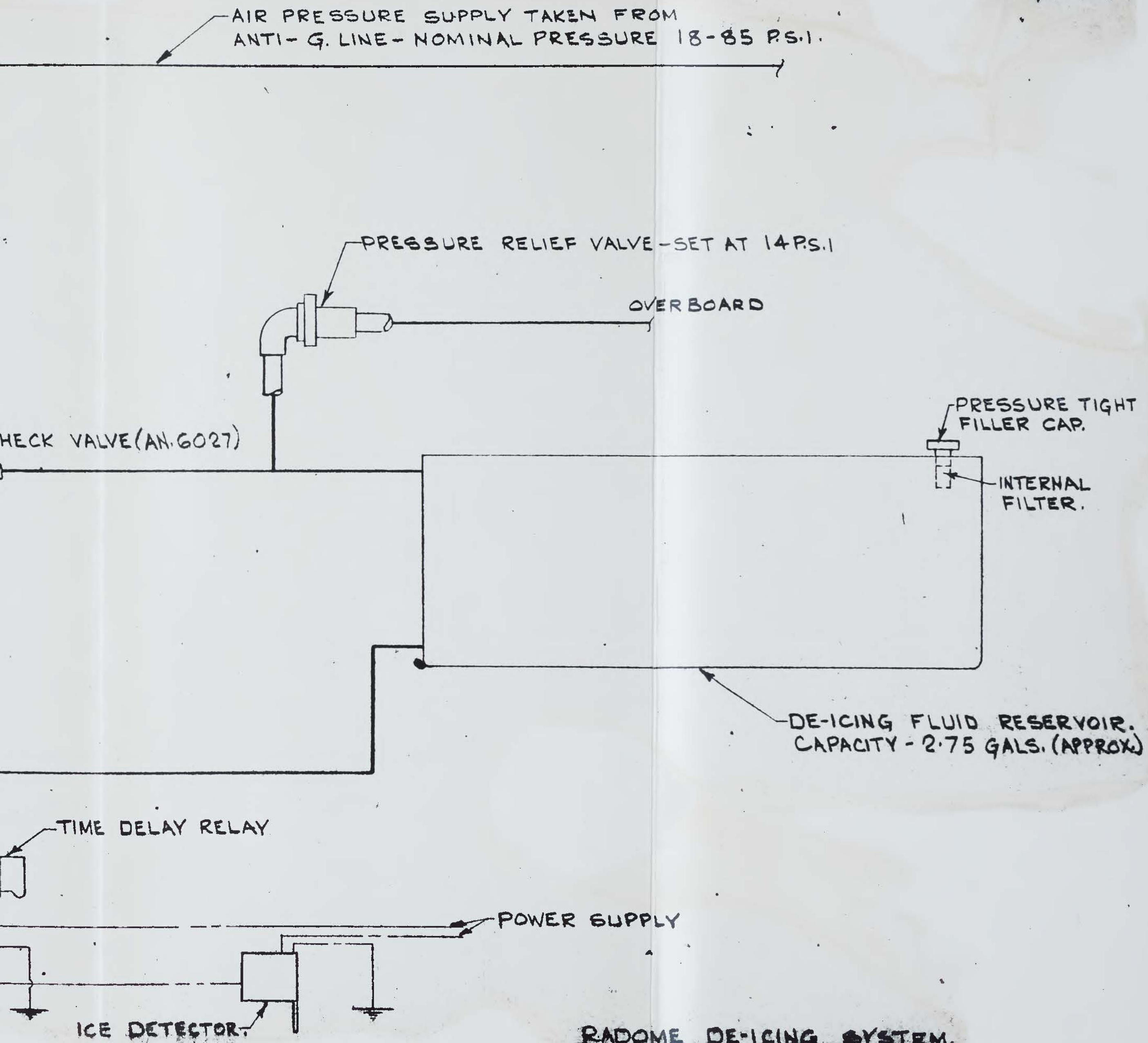


DIAGRAMATIC VIEW (SEE NOTE ABOVE)

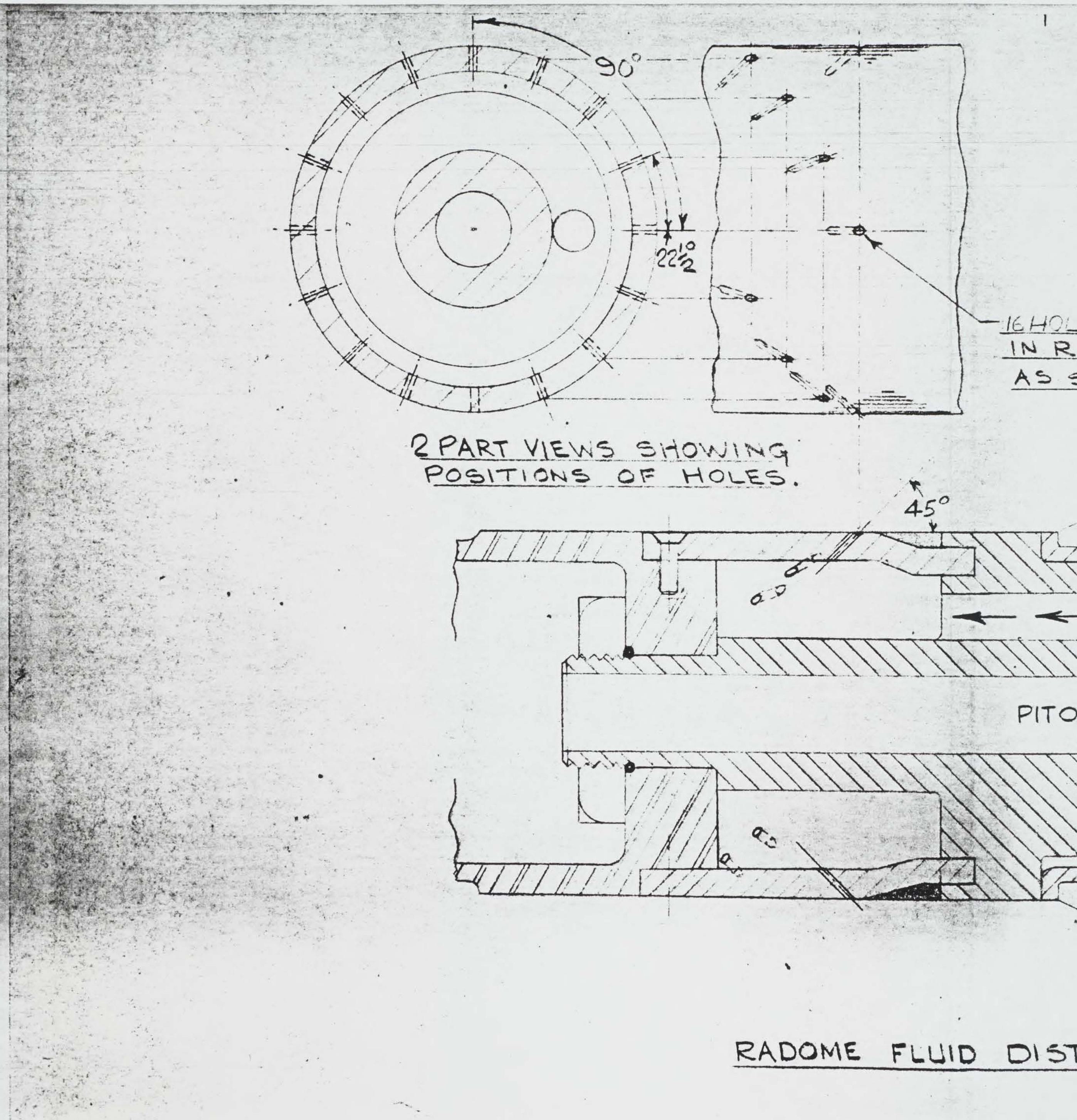
ICE DETECTOR IN DE-ICED CONDITION.

ICE DETECTOR – PRINCIPLE OF OPERATIONS.

FIG.1.3.1.

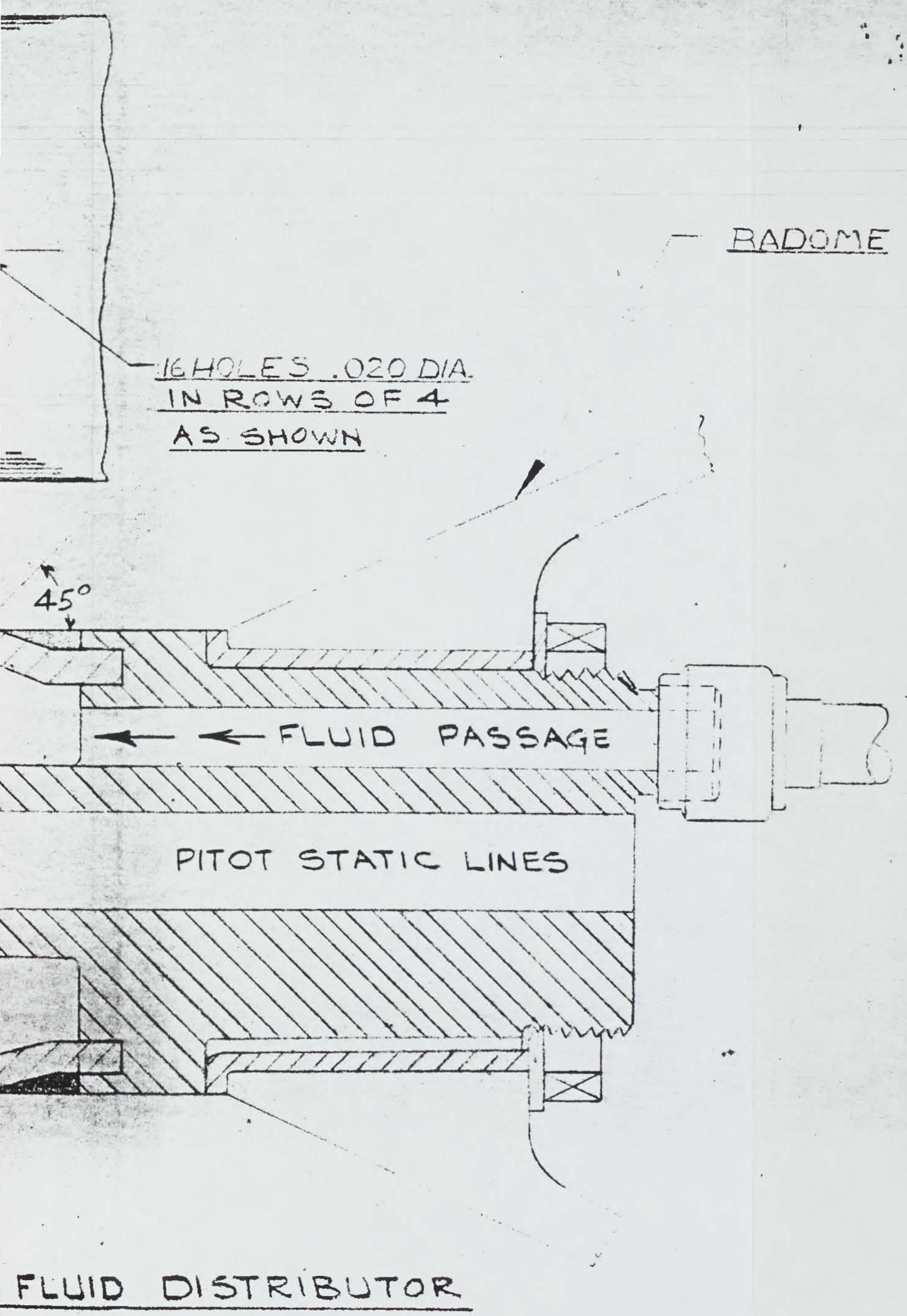


RADOME DE-ICING SYSTEM.



90°
22½°
16 HOL
IN R
AS S
2 PART VIEWS SHOWING
POSITIONS OF HOLES.
45°
PITO
RADOME FLUID DIST

FIG. 1.3.2.


RADOME
16 HOLES .020 DIA.
IN ROWS OF 4
AS SHOWN
45°
FLUID PASSAGE
PITOT STATIC LINES
FLUID DISTRIBUTOR