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Design and Development of Bogie Hinge Joint Flushing Device for the Safety Preservation of Aircraft Engines

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Abstract ;- Aircrafts need to be grounded for want of routine scheduled maintenance and inspection after certain period of flying hours. During such maintenance practices, the turbo-propeller engines are kept dismantled, un-installed and non-operative conditions for a longer period even up to two years. During this non-operative period, the engines and components are susceptible to extensive chronic corrosion hazards. To prevent this hazard, the engines and components are required to be preserved both internally and externally from corrosion that is the engine components such as turbine, turbine blades, compressor, fuel nozzles, fuel system pipelines, diffuser, combustion cum mixing chamber, expansion nozzle and exhaust manifold. *Over the long experience of operating the aircrafts, it has been observed that the appliance provided by the manufacturer is only meant for internal corrosion preservation purposes of the operative and installed engines and cannot be used for external corrosion preservation of non-operative and uninstalled engines which led to drastic reduction of engine lives and unsafe operating conditions to the aircrafts due to inherent materialistic corrosive effects.* The material of the turbine blades could not able to withstand its designed high combustion temperature due to the corrosion problems, which leads to unsafe engine conditions. The problem was attributable to the design factor that the high pressure cock in the fuel supply system could open and allow the preservative oil to enter into the main fuel system only when sufficient oil pressure is built up in associative oil system, which needs rotating the engines at least in idling speeds. Simulating this mandatory condition is not possible for the non-operative uninstalled engines.

To overcome the corrosion hazard problem of aircraft engines, a bogie hinge joint flushing device has been designed, fabricated and tested using the local resources after taking into consideration of this important engine external preservation requirements, layout of the turbo-propeller engine power plant and fuel supply systems. *This innovative external preservation rig has got multiple options coupled with internal preservation for preserving the engine components such as turbine, turbine blades, compressor, fuel nozzles, fuel system pipelines, diffuser, combustion cum mixing chamber, expansion nozzle and exhaust manifold during the course of long maintenance period*. The newly designed and developed external preservation rig has resulted in achieving the complete external preservation requirements of following categories of turbo-propeller engines.

(a) New/overhauled engines in storage and kept on expiry of preservation life
(b) Installed engine required to be removed for storage but can not be cranked or rotated
(c) Installed engines that are not in running condition/installation-seized engines.
(d) Uninstalled engine for defect investigation/defect rectification.
(e) Non operative unsafe engines

Key Words:- aircraft, engines, corrosion, unsafe, operation, repairs, maintenance, rig, preservation

1 Introduction

After certain hours of flying, aircraft needs to be grounded for want of routine scheduled maintenance inspections. During these inspections, the engines are kept non-operative for a longer period. During this non-operative period, the engines are susceptible to extensive chronic corrosion (Fig.1). The

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aircrafts are operated, maintained and parked in the moisture and marine environment of the coastal line full of salt deposits, which greatly aggravate the corrosive properties of material of engine components. The material of the aircraft, engine and associated equipments are subjected to heavy corrosion, various temperatures and weather conditions. The materials of the turbo-propeller engine components need to withstand high combustion temperature to which these are subjected. The preservation system is an on-line maintenance system exclusively meant for the operative installed engines and cannot be used for non-operative uninstalled engines, which led to the drastic reduction of engine lives and unsafe engine conditions. Over the long experience of operating the aircrafts, it has been observed that there is a necessity for an engine preservation system which will facilitate the testing of an aircraft engine using an external preservation rig for totally safest aircraft system which has zero material defect, zero breakdown and free from corrosion hazards while complying the safest material requirements.

2 Problem Formulation

The aircraft engines are the aerial altitude turbo propeller power plant operating jointly with a variable pitch propeller of left hand rotation (4). The turbo-propeller aircraft unit consists of the main units namely, a planetary reduction gear, a front casing, a ten stage axial flow compressor, an annular combustion chamber, a three stage axial turbine, a fixed area jet nozzle for high velocity jet as well as aircraft accessories. The air enters the aircraft turbo propeller unit at a velocity equal to that of the aircraft through a diffuser whereby the pressure of air rises to above atmospheric. A ten-stage rotary compressor axial flow type further compresses the intake air to a pressure of 6 bar and supplied to the annular combustion chamber (Fig.1). The liquid fuel under the pressure is injected and spayed into the combustion chamber by means of a pump through a ring of fuel nozzles. The fuel is burnt at constant pressure in the combustion cum mixing chamber. The products of combustion are then expanded in multi stage axial flow turbine where they lose some of their pressure thus imparting momentum to the turbine rotor and rotary motion to the turbine shaft. The products of combustion after expansion through the turbine are discharged through the nozzle(figure-1). The high velocity jet emerging out from the nozzle provides turbojet forward thrust energy to the aircraft. The turbine gives power to drive the axial flow compressor and variable pitch propeller. The speed of the propeller can be maintained and varied as per the requirements by a planetary reduction gear before the power is finally transmitted to the propeller (4).

2.1 Materials and Methods

1. Studying about the requirement of innovative engine external preservation rig
   The requirements of rig and the advantage of using the external preservation rig are presented.
2. The existing internal preservation rig for the engine is given in figure-2. The limitations with this rig have been studied. Considering the limitations, a new design of engine external preservation have been designed (Fig.3).
3. Technical requirements of the external preservation rig: Technical requirements for the external engine preservation have been carefully studied. The corrosion problems were identified, prepared, analyzed and evaluated in respect of engine external preservation requirements. Accordingly, an engine external preservation rig has been successfully designed, fabricated and evaluated. The figure 3 shows the bogie hinge joint flushing device, which is an innovative device or rig designed and developed for engine external preservation.
4. External preservation testing procedure of fuel manifold, combustion chamber, turbine blades are given in figure 4.
5. External preservation testing procedure of starting fuel manifold is provided in figure 5.
6. External preservation testing procedure of compressor gas flow path is given in figure.

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7. Studying the requirements of suitable material and spare parts for manufacturing the rig.
8. Method of Assembling: The joints are welded and tested by non-destructive method.
9. Carrying out functional check on ground: The test rig has been successfully tested and snags were rectified.
10. Carrying out trials on the non-operative uninstalled aircraft and identifying all the defects. Further necessary investigations, rectifications and modifications on existing system, equipment and indigenous activities will be preformed.

2.2 Characteristics of aircraft engine

Leading particulars

(a) Engine Type - Turboprop

(b) Propeller and engine rotor sense of rotation (If looking from jet nozzle) - Left Hand

(c) Reduction gear type - Planetary with torque- meter and negative thrust

Automatic feathering transmitter

Compressor Type - Axial flow

Number of stages - 10

Pressure rise ratio at normal Rating (H=8000 m V=175 m/sec) - 9.2

Compressor air blow off values

Number - 4 pcs, hydraulically controlled

Location - Two after fifth and two after eighth stages

3 Problem Solution

3.1 General construction, basic specifications, operating procedures and Drawbacks on existing internal preservation rig

3.1.1 General Construction

The appliance is essentially a welded tank. Arranged in the upper part of the tank are a pressure gauge, tank, filler neck, filter, compressed air delivery pipe connection and safety valve (Fig.2). A pipeline is connected to the air delivery pipe connection. Two reducers are built into the pipeline to reduce the pressure of the compressed air delivered to the tank from the ground compressed air source down to 149 kPa. There are two oil gauge glasses in the middle part of the tank to measure the oil level. Mounted at the bottom of the tank is an outlet pipe connection, which is connected to a pipeline with a built-in fine filter and value delivering oil into the engine. Connected to the value is a hose, which terminates in a pipe connection to be coupled to the engine. The tank is provided with two carrying handles. To ensure stability of the tank, the latter is placed on a cone-shaped support. Figure 2 depicts existing engine internal preservation (1).

3.1.2 Basic Specification

(a) Working pressure : 118 to 149 kPa

(b) Tank capacity : 0.04 m^3

(c) Overall dimensions:

- height : 610 mm
- base diameter : 450 mm

3.1.3 Drawbacks of internal preservation rig

(a) Internal preservation rig is not effective for complete corrosion preservation due to on-line maintenance practices and does not fulfill the preservation requirements.

(b) Operators require special training on operation of this rig.

(c) The rig is difficult to maintain operational aspects due to non-availability of spares.

(d) Prone to brushing due to requirement of pressurization.

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(e) It does not effect 100% preservation of the engines.

3.1.4 Construction, basic specifications, modified operating procedures of new rig

(A) Construction:

The rig comprises of a oil tank of 0.035 m^3 capacity instead of 0.040 m^3 as of original rig tank capacity was considered sufficient which is mounted on a base support and is welded with structure of cast iron angles. The tank has one in number delivery point from which oil is delivered through metal rigid pipeline to hand pump. The hand pump designed to build up pressure in the range of 74 to 99 kPa was obtained/retrieved from old unserviceable aircraft lifting jack. The overflow line from the hand pump is connected back in the suction/inlet line. The output of the hand pump is conveyed through flexible hose and various sprayers and adapters manufactured locally as per requirement to the engine points of preservation. Figure – 3 shows the newly designed bogie hinge joint flushing device for external preservation requirements.

(B) Basic specifications

(a) Capacity of oil tank : 0.035 m^3

(b)Hand pump output pressure range: 74 to 99 kPa

(c)Dimensions

Height : 750 mm

Length ; 1000 mm

Width ; 500 mm

Due to above modification/manufactured engine preservation rig, the operating procedure (from one point to other point) also happened to change in small stops in the previous procedures which is followed by us as per technical operating instructions manual and maintenance manual.

The new procedures are given below:

(C) Operating procedures for preservation from engine preservation point to fuel Inlet are as follows

(a) Remove and wash the engine fuel fine, coarse filters and fuel filter.

(b) Open the blanking cover from the combustion chamber drain.

(c) Connect the outlet pipeline connection of preservation rig through which the corrosion preservative oil (OM 11) is delivered to engine fuel system, to aircraft preservation point.

(d) Disconnect the fuel inlet connection to fuel control unit of aircraft engine.

(e) Start pumping the hand pipe on the preservation trolley to allow preservation oil into the fuel system.

(f) During the process of supplying oil into the system crank the engine if possible by rotating the propeller, to augment the flow of oil.

(g) Pump in 0.01 to 0.015 m^3 of oil (OM 11) into the system and ensure flow of preservation oil (hot) from the outlet of engine high-pressure pump.

(h) Disconnect the preservative oil line connection and blank engine preservative point.

(D) Operating procedures for preservation of fuel control unit of the engine are given below.

(a) Connect outlet connection of engine internal preservation device to fuel inlet of filter.

(b) Disconnect the filter and fuel outlet pressure transmitter connection.

(c) Pump in the preservative oil into filter and watch for the flow of hot preservative oil from the preserve transmitter outlet.

(d) Disconnect all the external connections and give connection of disturbed pipelines and wire lock it.

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(E) Operating procedures for preservation of fuel manifold, combustion chamber, turbine blade, 20% Fuel by pass line and starting manifold with igniters as appended below . Figure- 4 depicts the external preservation procedures for fuel manifold, combustion chamber, turbine and fuel systems. Figure –5 depicts external preservation procedures for starting manifold

(a) With the help of 'V' shaped three way union, connect one end of three way union to the outlet pipe line connection of flushing device through which the preservation oil (OM-11) is delivered to fuel manifold, and the other end to air trolley. Connect the outlet of three union to inlet of fuel manifold (Figure-4)

(b) Pump in preservative oil (OM 11) and at same time supply 399 to 495 kPa of compressed air at the other end of union.

(c) During the process of supplying oil into the system, crank the engine with the help of a propeller. Do not crank, if the engine is seized.

(d) Watch for the oil vapour at engine exhaust and ensure the presence of oil coating on the last stage of turbine by visual check.

(e) Disconnect 'V' shaped three way union connection from fuel manifold inlet and pump in preservative oil OM 11 into fuel manifold inlet with help of flushing rig for 1 to 2 minutes and at same time give 28 V DC external supply to 20% fuel by pass electromagnetic valve for preserving the fuel by pass line (Figure-5).

(f) Confirm sufficient amount of oil drained from the combustion chamber drain point.

(g) For preserving starting fuel manifold and igniters, connect the preservative oil connection from the flushing rig to inlet of starting fuel manifold. Pump in preservative oil for 2 to 3 minutes and the same time open the electromagnetic valve with help of 28 V DC external power supply (Figure-5).

(F) Operating procedures for external preservation of engine compressor.

(a) Prepare new engine internal preservation device. Clean and flush the tank and pipes lines with the help of preservative oil (OM-11)

(b) With the help of 'V' shaped three way union, connect one end of three way union to the outlet pipe line connection of flushing device through which the hot preservation oil (OM-11) is delivered to compressors and the other end to air trolley. See figure 5 and 6 for reference.

(c) Start pumping the preservation oil and the same time supply compressed air at pressure of 495 to 590 kPa by holding the outlet of the 'V' shaped three way union facing towards the compressor blades to spray in a mixture of air and oil into the gas flow bath of compressor.

(d) While supplying oil into the compressor, crank the engine exhaust.

(e) Incase of engine cranking not feasible, preserve compressor by holding the outlet of the 'V' shaped three way union outlet facing all around the compressor inlet.

(f) For preserving the last stage of turbine to a full extent, deliver preservative oil (OM-11) under air pressure from the turbine side and crank the engine with the help of propeller.

(g) Confirm sufficient amount of oil drained from the

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combustion chamber drain point.

3. 2 Effect of engine performance on corrosion effects

1. As per the engine heat balance sheet, there is 20-24% identified heat loss took place which reduces the performance of the engine.
2. Engine does not run at economical speed conditions with respect to minimum brake specific fuel consumption, minimum frictional power and maximum availability of brake power.
3. Performance deterioration due to the non-compliance of optimum heat transfer requirements to power at brakes, cooling and exhaust system.
4. Drastic reduction in combustion efficiency because of incomplete combustion.
5. The air-fuel ratio and temperature in the gas turbine is be maintained as 60 : 1 and 1250 °C respectively. The net turbo propulsion thrust is equal to the sum of turbojet thrust plus propulsion thrust. During the longer maintenance period, corrosion takes place over the engine and associated pipelines. The corrosion hazards over the materials cause the reduction in engine lives with the resultant unsafe conditions. The metallurgical properties will vary in respect of corrosive materials with deficiency in resistant to the designed combustible temperature. Hence, engine deterioration takes place in improper maintenance of the air fuel ratio and temperature and thus causing engine seizure with the resultant curtails of output power and thermal efficiency. Due to the corrosion hazards, the net turbo propulsion thrust has been reduced considerably to 20%.

Conclusion

After certain hours of flying, aircraft needs to be grounded for want of routine scheduled maintenance inspections. During these inspections, the engines are kept non-operative for a longer period. During this non-operative period, the engines are susceptible to extensive chronic corrosion. Over the long experience of operating the aircrafts, it has been observed that there is a necessity for an engine preservation system which will facilitate the testing of an aircraft engine using an external preservation rig for totally safest aircraft system which has zero material defect, zero breakdown and free from corrosion hazards while complying the safest material requirements.

To avert the corrosion hazard problem of aircraft engines, a bogie hinge joint flushing device has been designed, fabricated and tested using the available resources after taking into consideration of this important engine external preservation requirements, layout of the turbo-propeller engine power plant and fuel supply systems. *This innovative external preservation rig has got multiple options coupled with internal preservation for preserving the engine components such as turbine, turbine blades, compressor, fuel nozzles, fuel system pipelines, diffuser, combustion cum mixing chamber, expansion nozzle and exhaust manifold during the course of long maintenance period*. The newly designed and developed external preservation rig has resulted in achieving the complete external preservation requirements of following categories of turbo-propeller engines.

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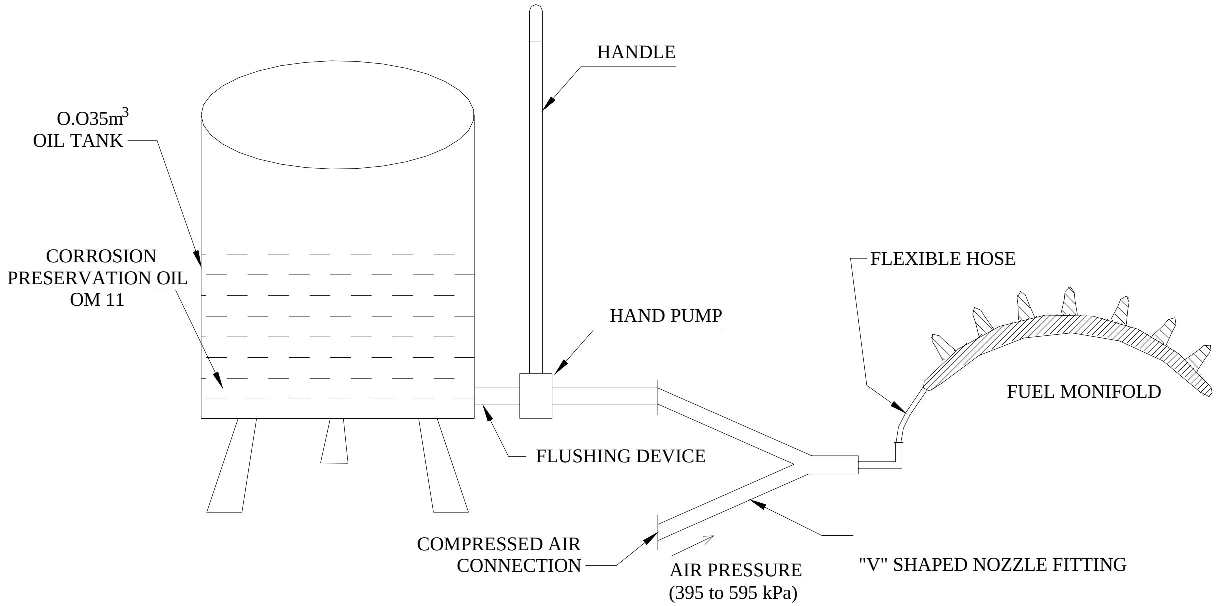

Fig 4. External preservation testing procedure of fuel manifold, combustion chamber and turbine blades

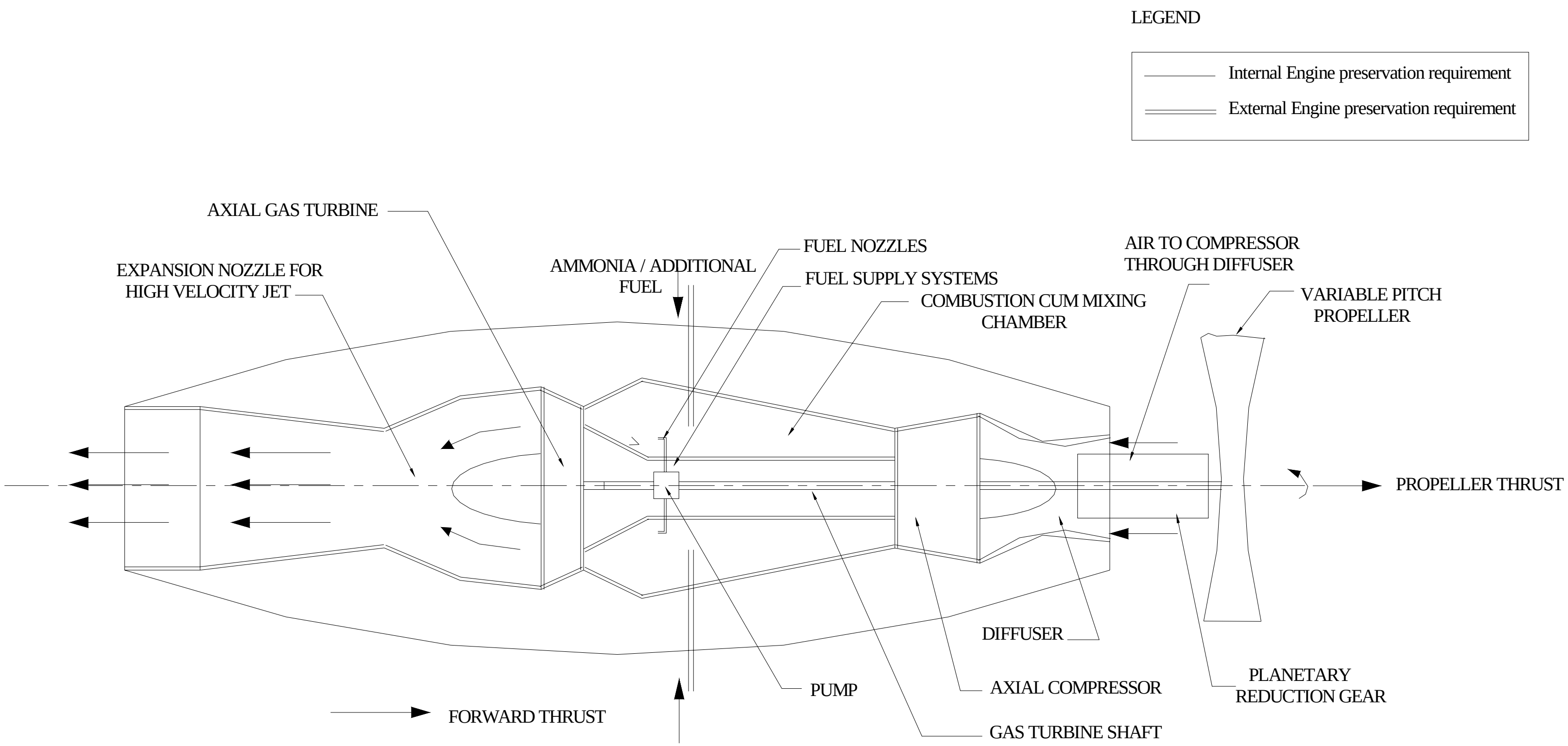

Fig 1. General engineering layout of turbo propeller aircraft showing internal and external corrosion preservation requirements

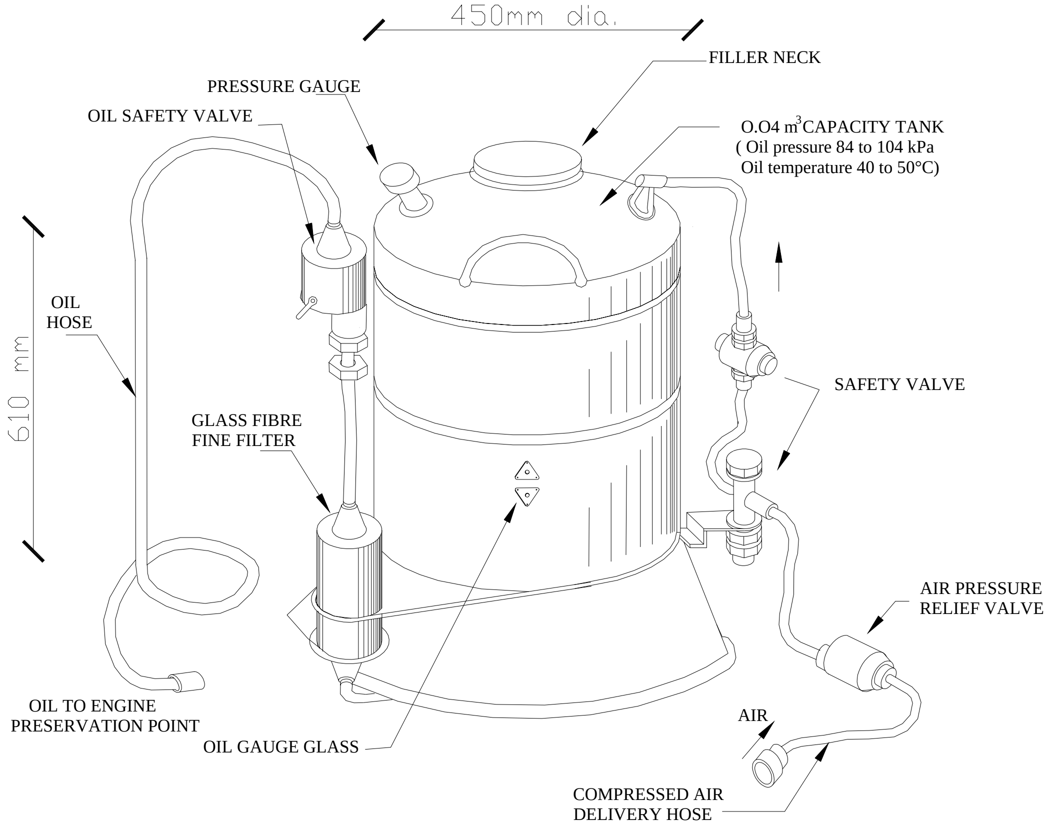

Fig 2. Existing engine internal preservation rig

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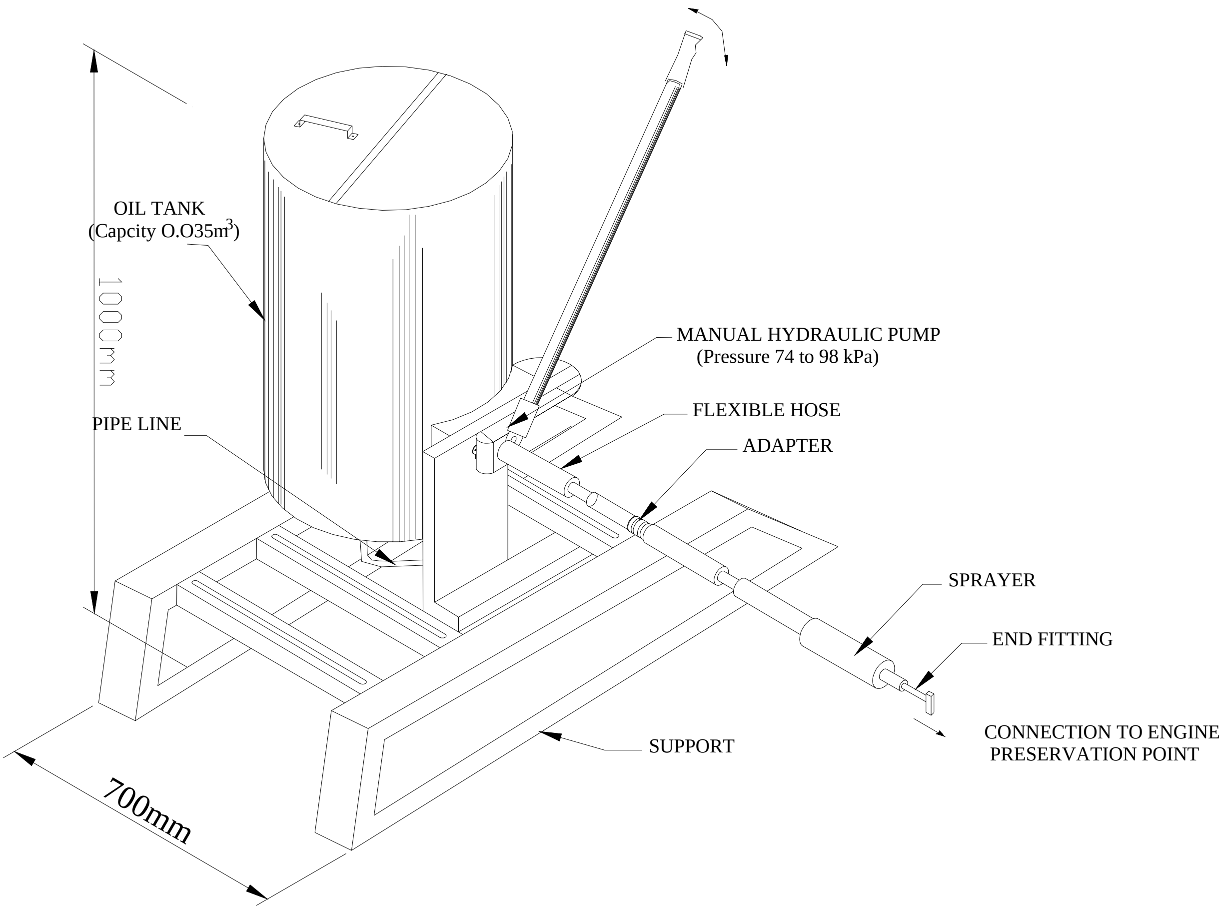

Fig 3. Newly designed bogie hinge joint flushing device for engine external preservation requirements

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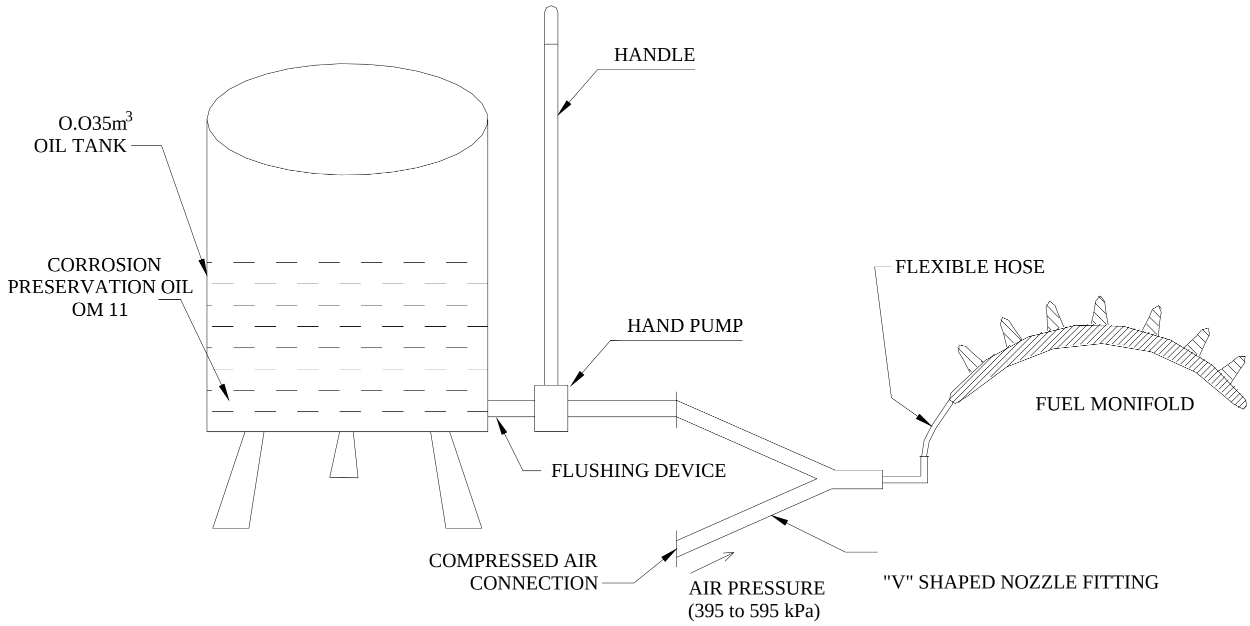

Fig 4. External preservation testing procedure of fuel manifold, combustion chamber and turbine blades

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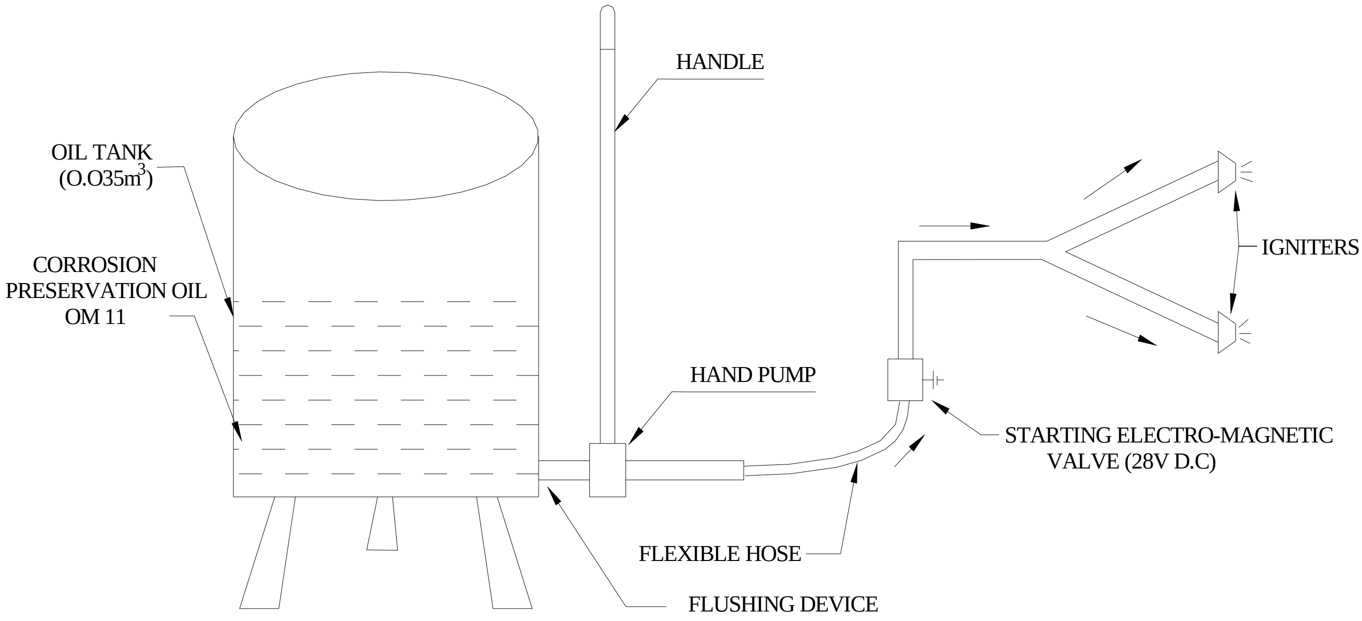

Fig 5 External preservation testing procedure of starting fuel manifold

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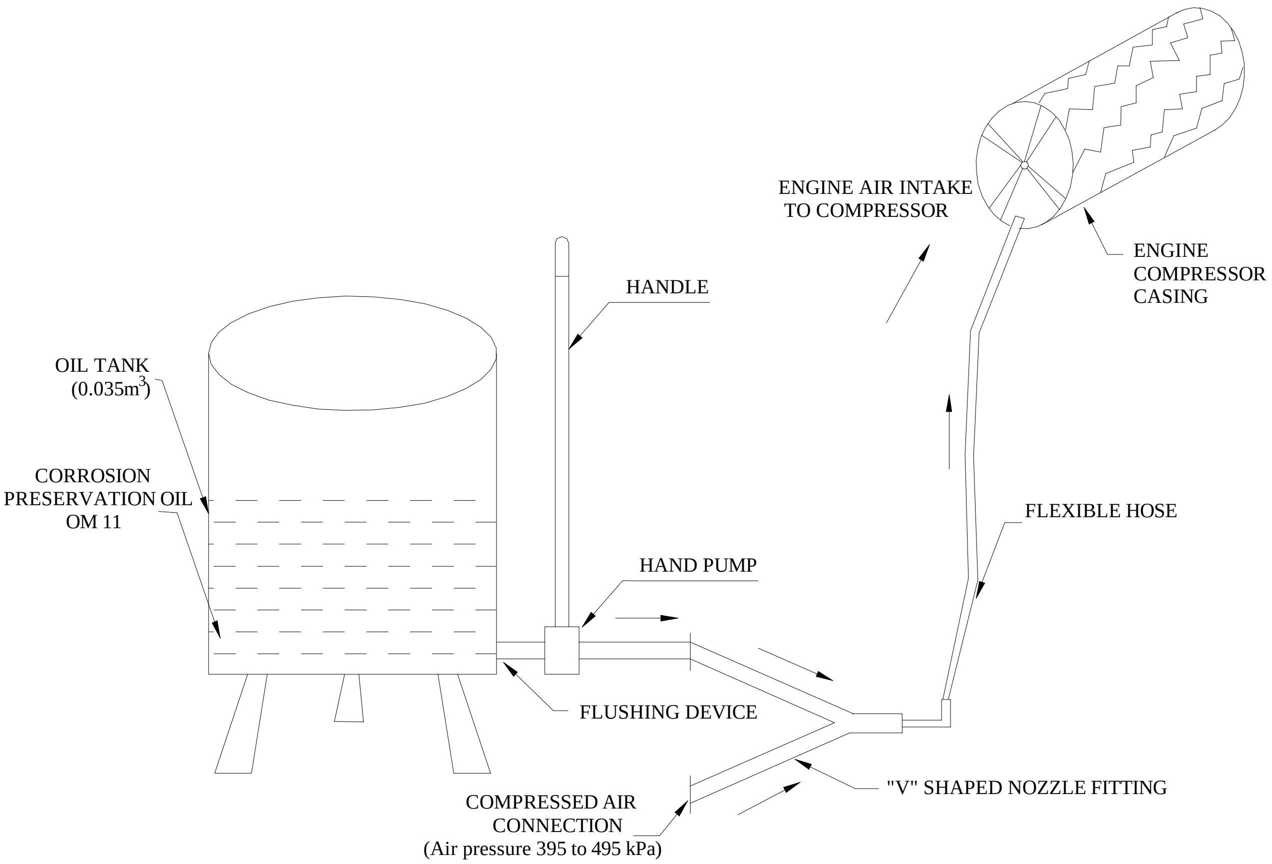

Fig 6 : External preservation testing procedure of axial compressor air flow path