

STANDARD OPERATING PROCEDURE AND SAFETY GUIDE FOR ROVER GAS TURBINE APPARATUS

(Located in Rm. H-17 Head Hall)



Prepared

May 16, 2010

Table of Contents

1. Scope.....	4
1.1 Objective.....	4
1.2 Regulations	4
2.Apparatus Overview and objective.....	4
2.1 Apparatus overview	4
3. Hazards and control evaluation.....	21
3.1 Possible fire event	21
3.2 Ventilation.....	21
3.3 Kinetic, thermal & accoustic.....	22
3.4 Electrical	25
3.5 Fuel and Water	26
3.6 General, physical & equipment concerns	28
3.7 Access	30
3.8 Training.....	30
3.9 Personal equipment.....	30
4. Operation.....	30
4.1 Qualified personnel.....	30
4.2 Experiment preparation.....	30
4.3 Lab instructions.....	32
4.4 Operating procedure.....	34
5. Inspections	36
5.1 Operational & Periodic inspections	37
6. Typical test.....	37
Appendix A: Lab Script.....	38
Appendix B: Rover 60 hp gas turbine engine.....	39
Appendix C: Operator’s Handbook	40
Appendix D: Spare Parts Catalogue	41
Appendix E: Heenan-Froude Dynamometer	42

H-17, Head Hall floor plan

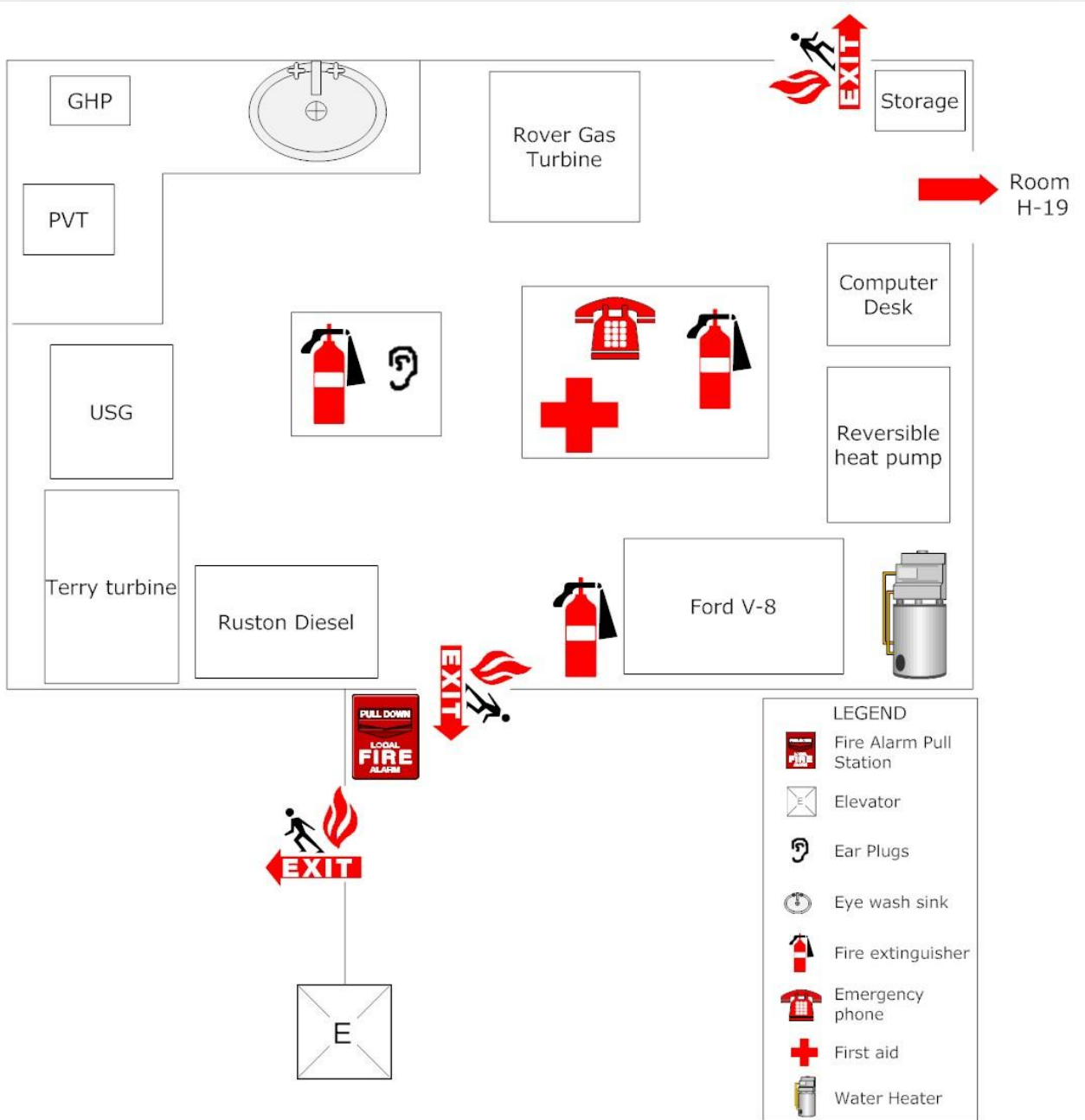


Figure 1: H-17, Head hall floor plan

1. Scope

1.1 Objective

This standard operating procedure is intended to provide operating instructions and safety information for the Department of Mechanical Engineering's Rover Gas Turbine experiment apparatus located in H-17, Head Hall. This document is intended as a guideline and supplement to proper training that must be provided by qualified personnel before the apparatus is operated. The aim of this document is to ensure that safe work practices have been developed for the Rover Gas Turbine experimental work. This SOP is primarily concerned with the operating procedure of the apparatus, hazards involved in the experiment and safety precautions that must be taken to avoid injuries.

1.2 Regulations

This document has been developed in accordance with the Environmental Health and Safety Office of the University of New Brunswick.

2. Apparatus Overview and Objective

2.1 Apparatus overview

The experimental apparatus admits ambient air through two sideways **air intakes** into the **compressor housing**. There is an **airmeter thermometer** mounted on the intake of **airmeter** to measure the temperature of air being pulled in to the IS/60 engine. The Airmeter has a 4.5 inches diameter venturi in it for computation of the air mass flow. The **compressor** in the compressor housing is a single stage centrifugal pump and consists of a 17 guide vanes impeller machined from an aluminum alloy forging. The vanes of the impeller have curved leading edges to assist air entry into the eye of the impeller. The air is then pumped by the blades of the impeller to the **reverse flow combustion chamber** of the IS/60 engine. The combustion chamber consists of an **igniter plug** which is connected to a **battery** via an **igniter box** and a **keyed ignition**. When the starter key is turned clockwise (3rd position) on the keyed ignition, the engine starts up with the compressor pumping air into the combustion chamber and out of the apparatus through exhaust. The engine is running on battery power until it reaches a constant RPM of about 4000 RPM, then the fuel operating lever is opened and the igniter plug on combustion chamber produces sparks which in turn start the combustion of air/fuel mixture in the combustion chamber.

There is a **fuel burner**, **fuel operating lever** and **fuel accumulator bulb** on the apparatus. The fuel burner contains a fuel atomizer, which sprays jets of fuel into the combustion chamber for the combustion process. The fuel operating lever connects/disconnects the fuel supply to the combustion chamber by controlling a fuel shut-off valve in the fuel burner. The fuel accumulator stores fuel under pressure and ensures good fuel atomization for engine starting purposes. The fuel accumulator is always unscrewed before starting the experiment to purge trapped fuel that has already collected, into a beaker/bottle. It is then screwed tight again to proceed with the experiment. Please see figure 2, 3 and 4 for details and description of the components.

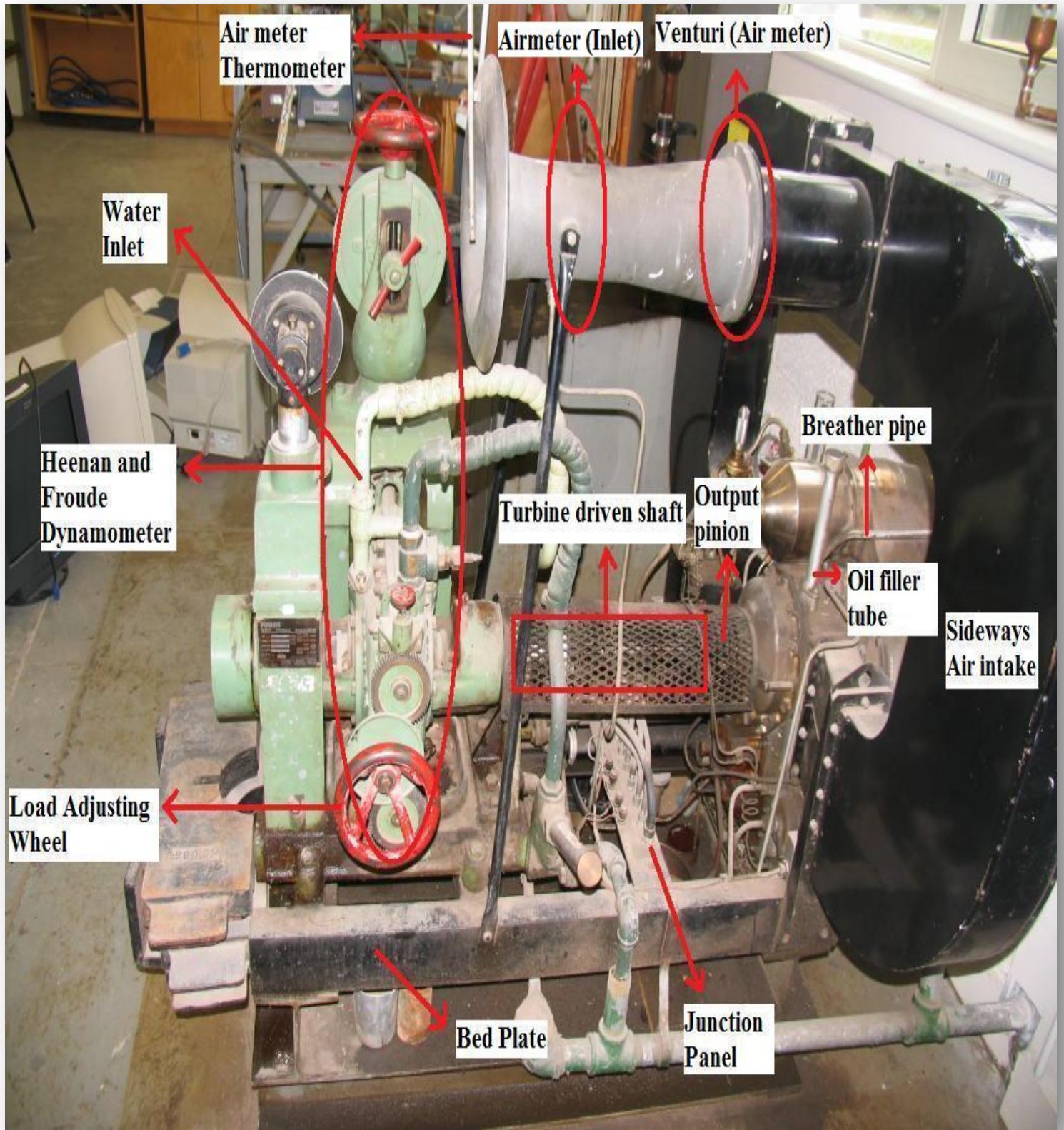


Figure 2: Apparatus components overview

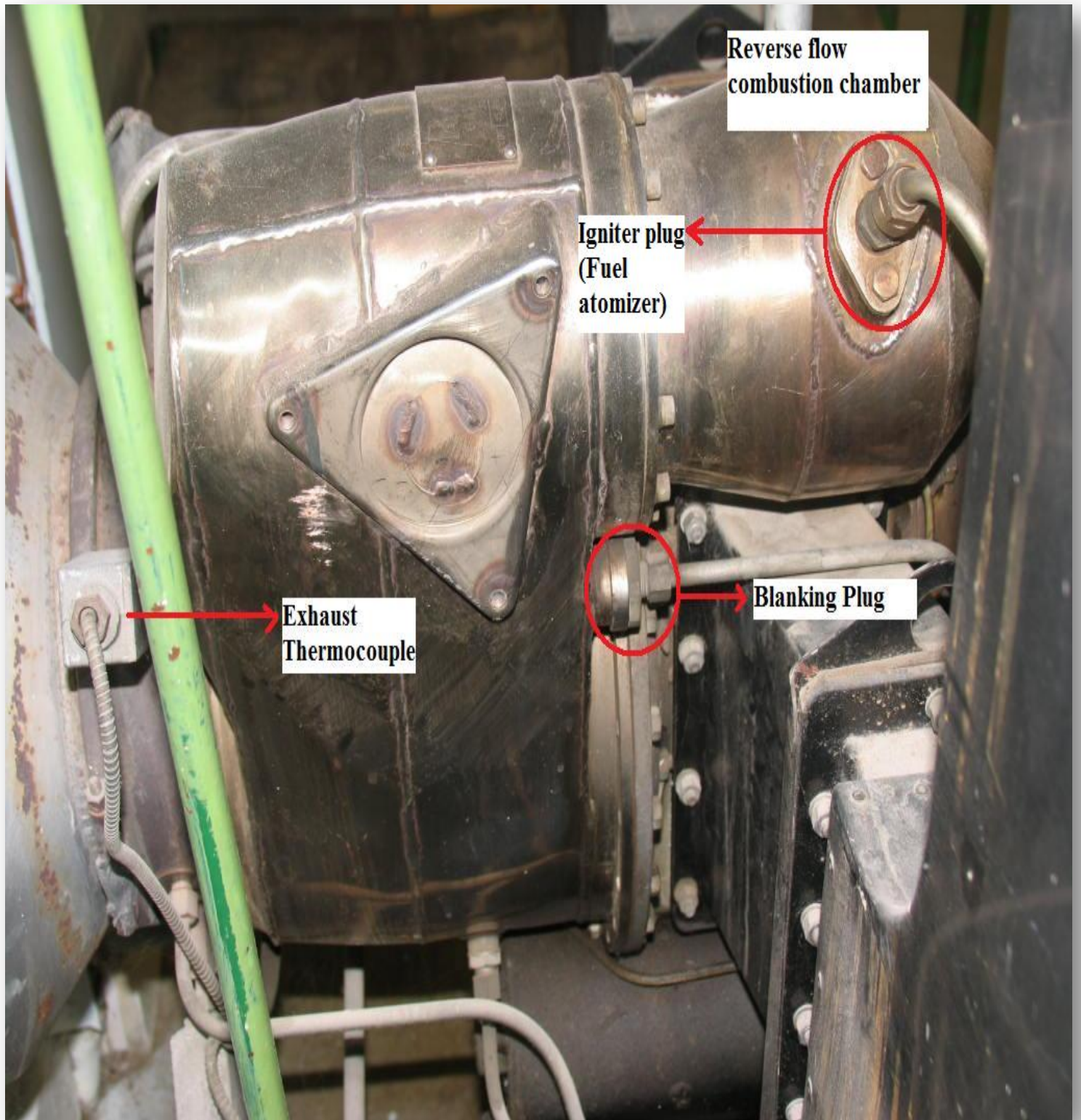


Figure 3: Apparatus components overview

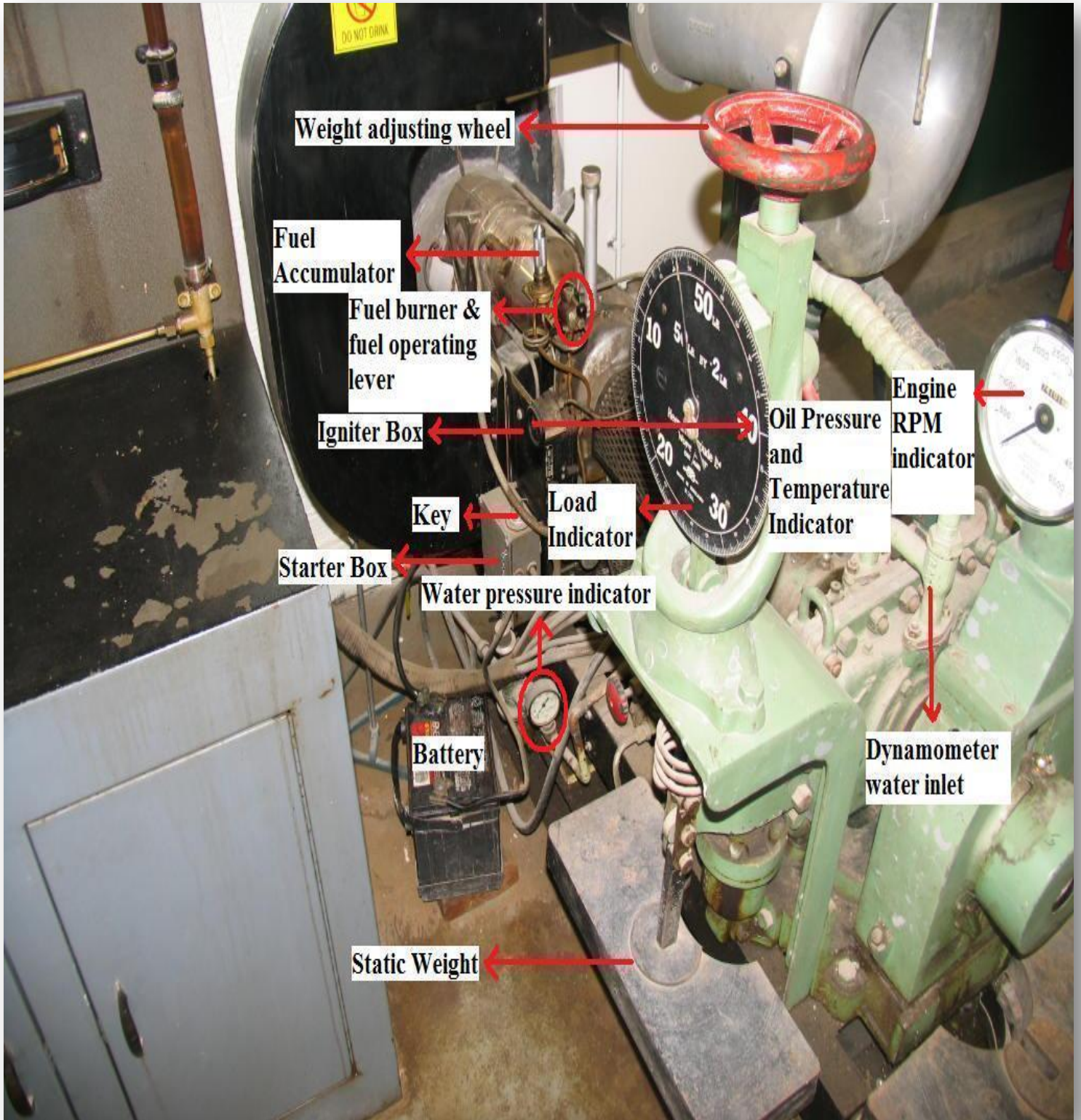


Figure 4: Apparatus components overview

The hot gases from the combustion chamber are guided through volute (air passage assembly) to the **turbine** rotor, where the gases expand against the **single stage axial turbine** and work is done. The turbine is a nimonic forging in which the blades and disc are machined integrally. The blades are of free vortex design. The turbine rotor is attached to the compressor shaft by a single large diameter nimonic bolt. The **main air casing** of the apparatus consists of a **fuel drain assembly** and **oil drain assembly** (oil drain assembly drains the used oil into the oil sump). Bolted to the front face of the compressor housing is the aluminum alloy **auxiliaries mounting plate** to which are attached both the **oil pump** and the **fuel control unit**. The fuel control unit consists of a centrifugal type governor to avoid over speeding of the engine by controlling the amount of fuel to the combustion chamber. The unit also has a fuel filter in it. There is a temperature control located in the exhaust and connected to the fuel control unit, which prevents the engine from operating at excessive temperatures by operating a valve to return fuel to the suction side of the pump at a predetermined exhaust temperature and reducing the amount of fuel to the combustion chamber. The oil pump and fuel control units are both driven from the turbine shaft by an internal **train of reduction gearing**. The IS/60 engine has a 3000 RPM reduction gearing and the turbine **output pinion** in the centerline of compressor and turbine assembly protrudes outward from the meshed gears. The output pinion rotates counter clock wise when viewed from the rear of the IS/60 engine.

The output pinion is connected to the **Heenan and Froude type dynamometer** assembly. The engine and dynamometer are mounted on a fabricated **mild steel bed plate** of substantial channel section. The amount of load on the IS/60 engine is controlled by a **load adjusting wheel** which is turned to increase or decrease the load on the IS/60 engine. If the load is increased, the RPM of the engine decreases and to keep the RPM constant a **throttle lever** on the control desk is used to increase/decrease the RPM of the engine, and **RPM indicator** displays the RPM of the engine. The **weight adjusting wheel** is turned to balance the dynamometer assembly (see figure 2, 4 & 5 to understand the dynamometer assembly and how to balance the dynamometer). Please refer to Appendix 'A' (Heenan - Froude Dynamometer) to completely understand the working of Heenan & Froude dynamometer. Also see figure 6 and 7 for details and description of the apparatus components.



Figure 5: Apparatus components overview

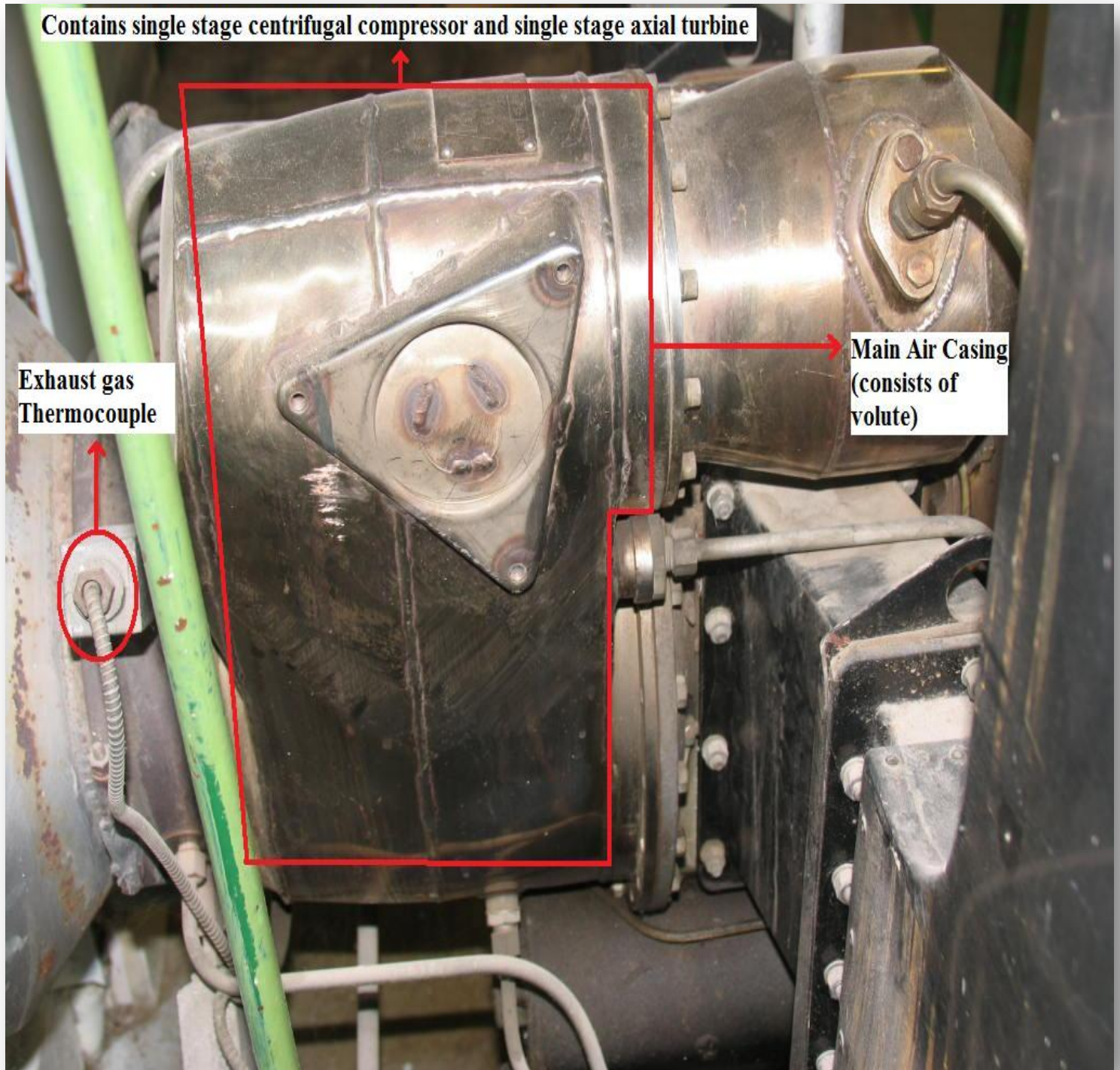


Figure 6: Apparatus components overview

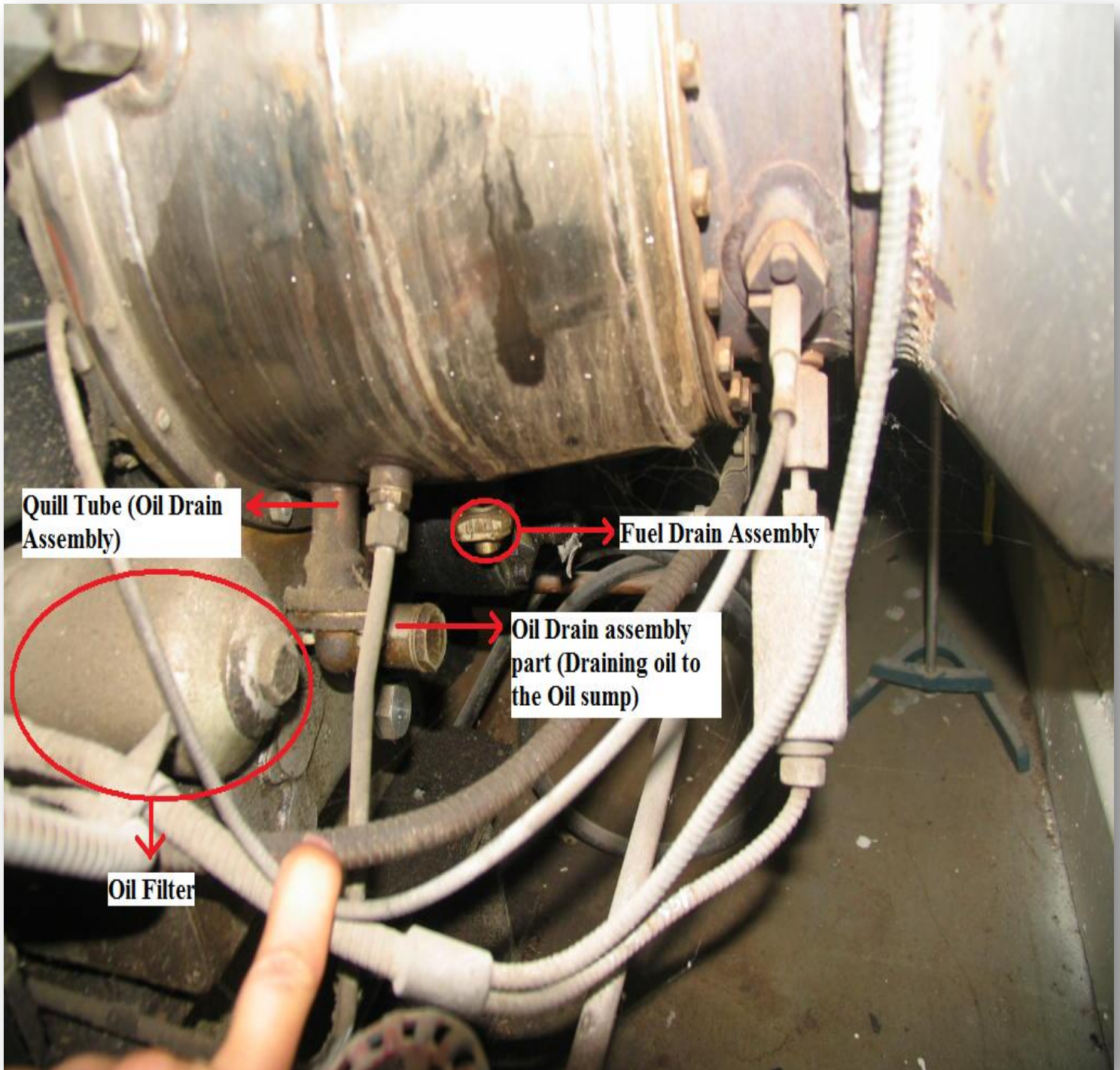


Figure 7: Apparatus components overview

The apparatus consists of a **control desk**, which has a **fuel tank** located at its top. The fuel is pumped in to the fuel tank by a **fuel pump** located at the bottom of control desk. The fuel flow from the **main fuel storage tank** (located outside the

H-17 Lab) to the fuel pump is controlled by **main fuel supply** valve. There are number of pressure and temperature displays of the apparatus on the control desk during operation of the apparatus. The **impeller tip pressure gauge** and **compressor delivery pressure gauge** measure and display the impeller tip pressure of the compressor and entering air pressure of the compressor. The exhaust gases are exhausted through an **exhaust extension** and there is an **exhaust temperature indicator** on the control desk to display the exhaust gases temperature. The control desk has a **measuring flask** mounted on it to measure the amount of fuel consumed by the engine. There is also a **compressor delivery temperature indicator, exhaust temperature indicator, airmeter depression manometer** and **turbine outlet static pressure manometer** mounted on it to display the temperatures and pressures as desired by the user. There are total 5 **thermocouples** connected to the apparatus, one for the compressor delivery temperature and the rest for the exhaust gases temperature. The thermocouples are connected to the control desk to display the temperatures via a **junction panel**. Please see figures 8, 9 and 10 for details and description of the apparatus components.

Please refer to Appendix 'B' (Rover 60 hp gas turbine engine) to see the details on the technical data and specifications of the engine, lubrication system, fuel system, electrical equipment, dynamometer and instrumentation.

Please refer to appendix 'C' Operator's handbook to see the specifications of the components of the apparatus and also refer to appendix 'D' (spare parts catalogue) to see the complete details and description of all the components and parts of the apparatus.

The purpose of the Lab is to operate the Rover gas turbine at a constant speed at an increasing load as provided by the dynamometer. The fuel consumption is monitored as well as the various pressures and temperatures.



Figure 8: Apparatus components overview

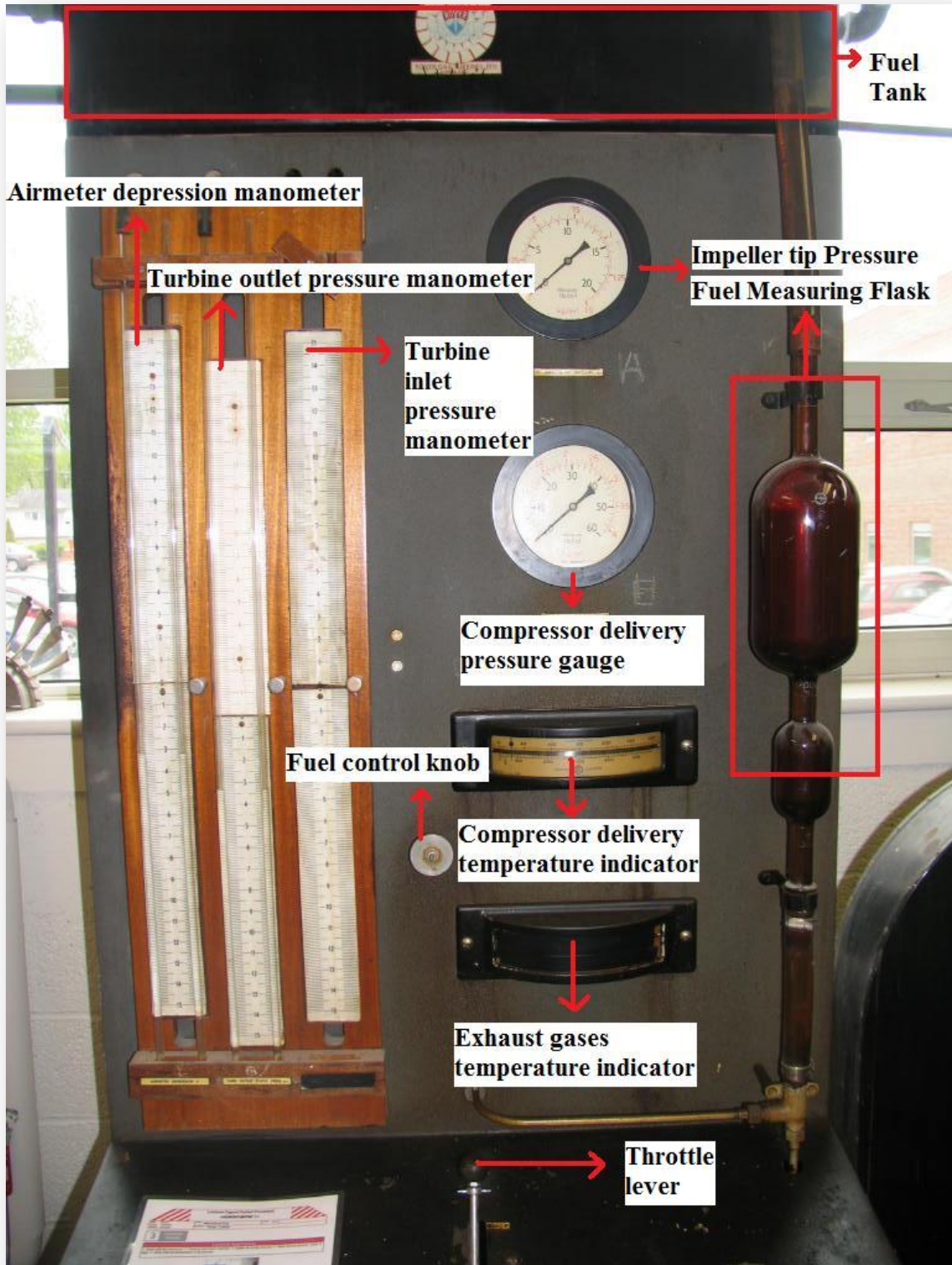


Figure 9: Apparatus components overview

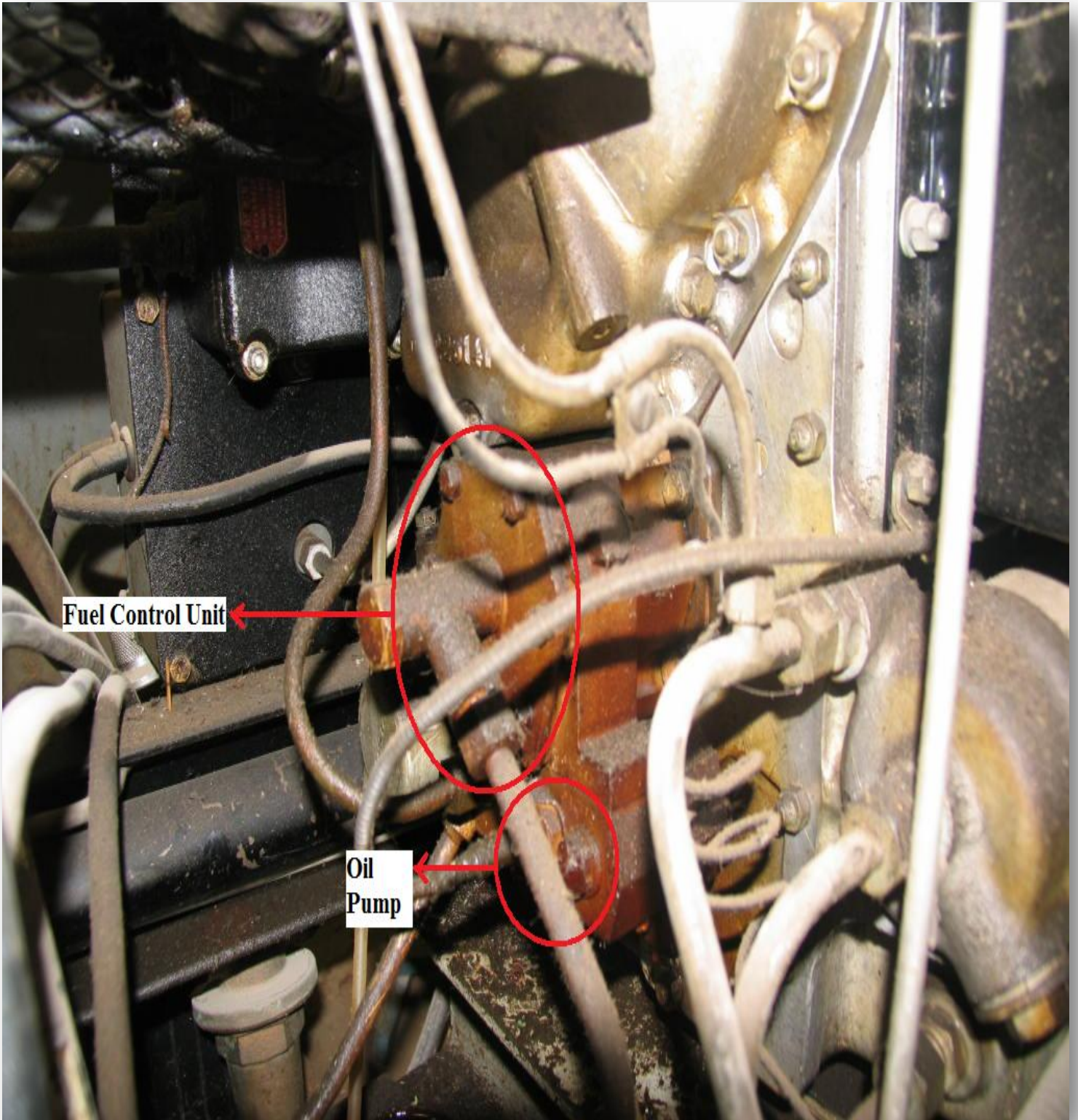


Figure 10: Apparatus components overview

The compressor housing consists of an **oil return pipe** in front and an **oil sump** at the bottom. The oil sump collects the oil already used by the IS/60 engine/Rover Gas Turbine and has the capacity of five pints. The used oil in the oil sump can be drained by unscrewing the **oil sump drain plug**. There is an **oil temperature bulb** screwed with the oil sump to measure the temperature of oil in the sump and the temperature is indicated on **oil temperature gauge**. Please see figure 11 and 12 for details and description of some of the other important components of the apparatus

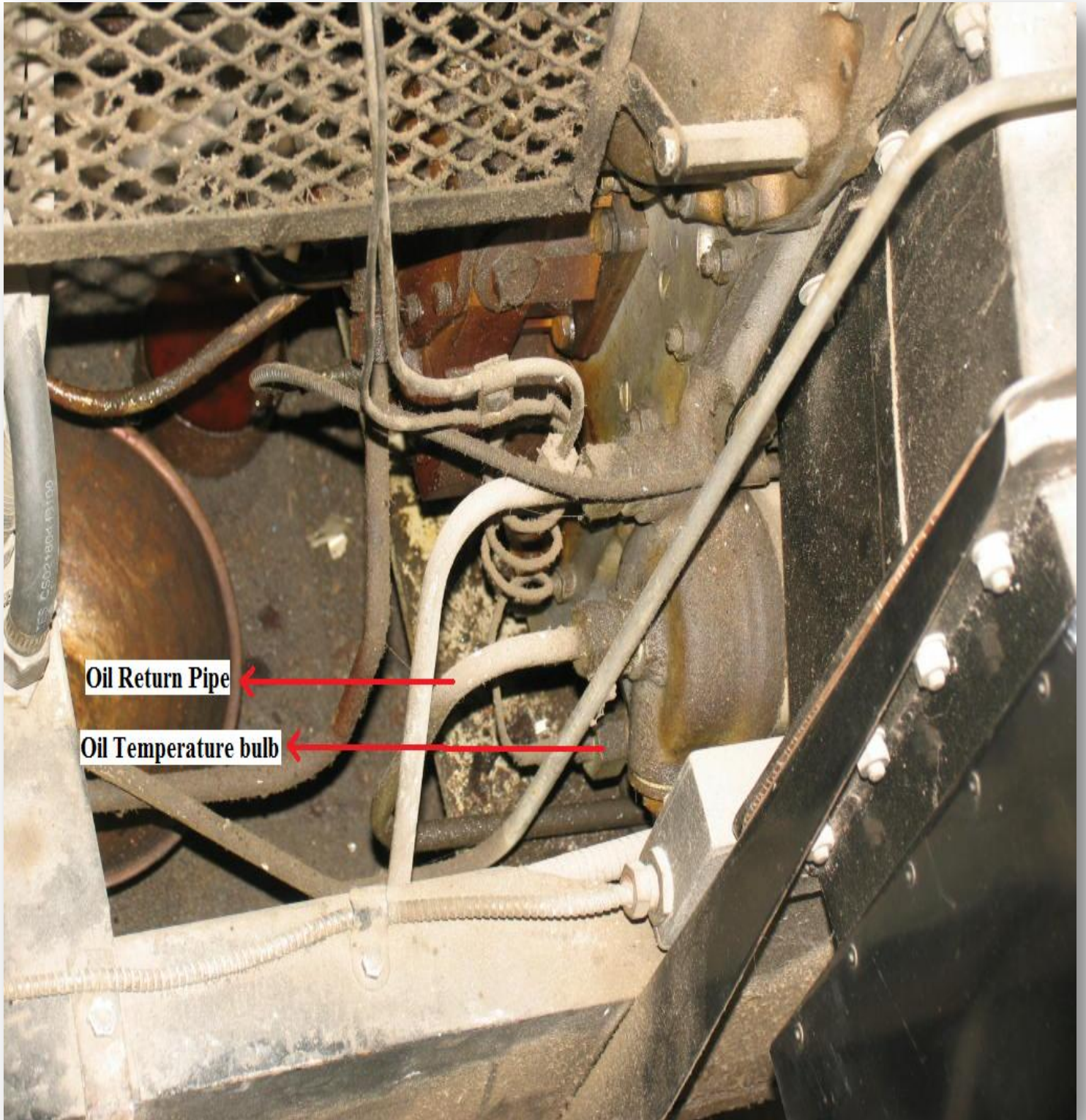


Figure 11: Apparatus components overview

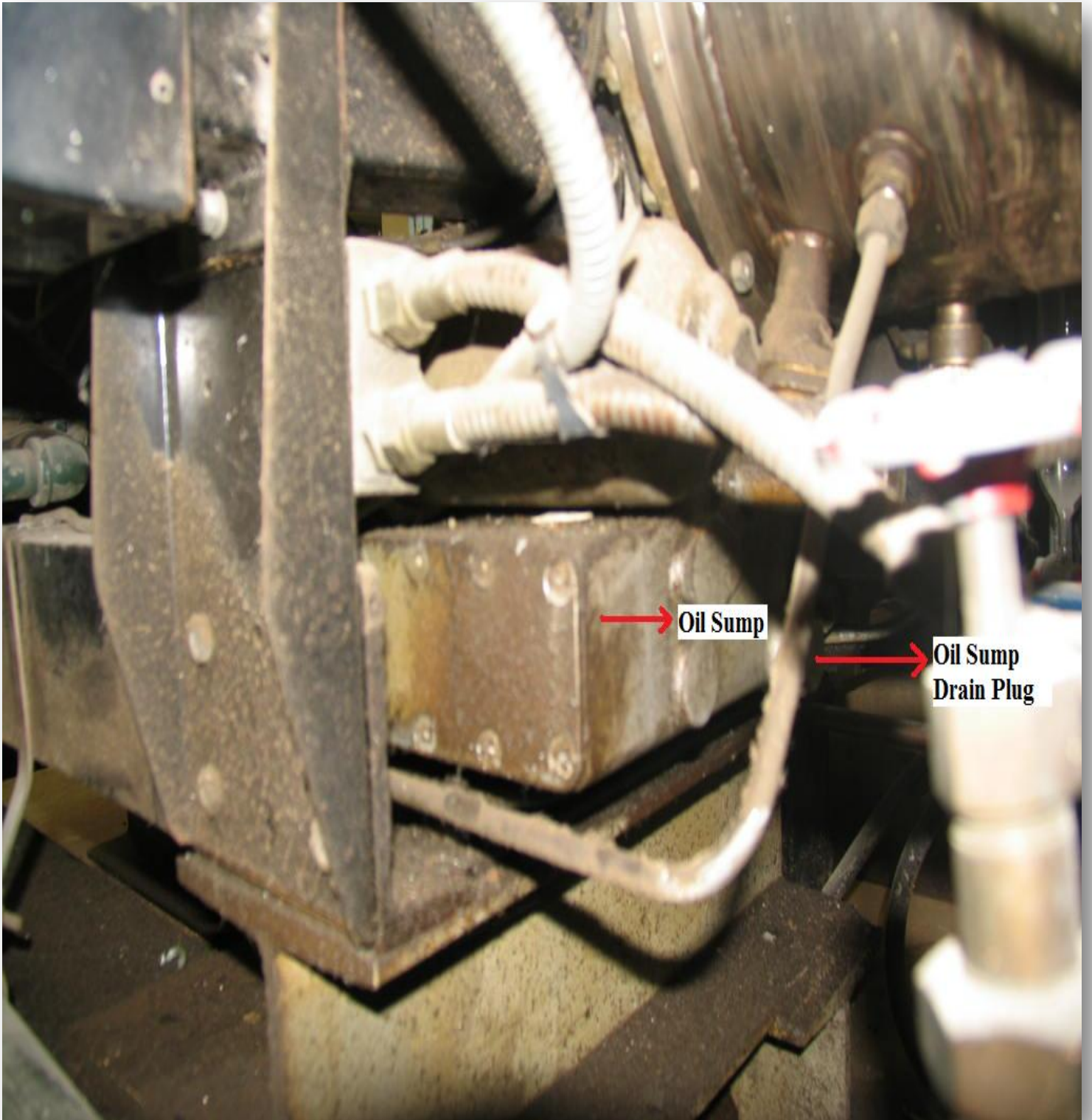


Figure 12: Apparatus components overview

The pressure of oil pumped into the **oil filter** is measured and indicated on the **oil pressure gauge**. There is an **oil level dipstick** to check the oil level in the IS/60 engine. Please see figure 13 below for description

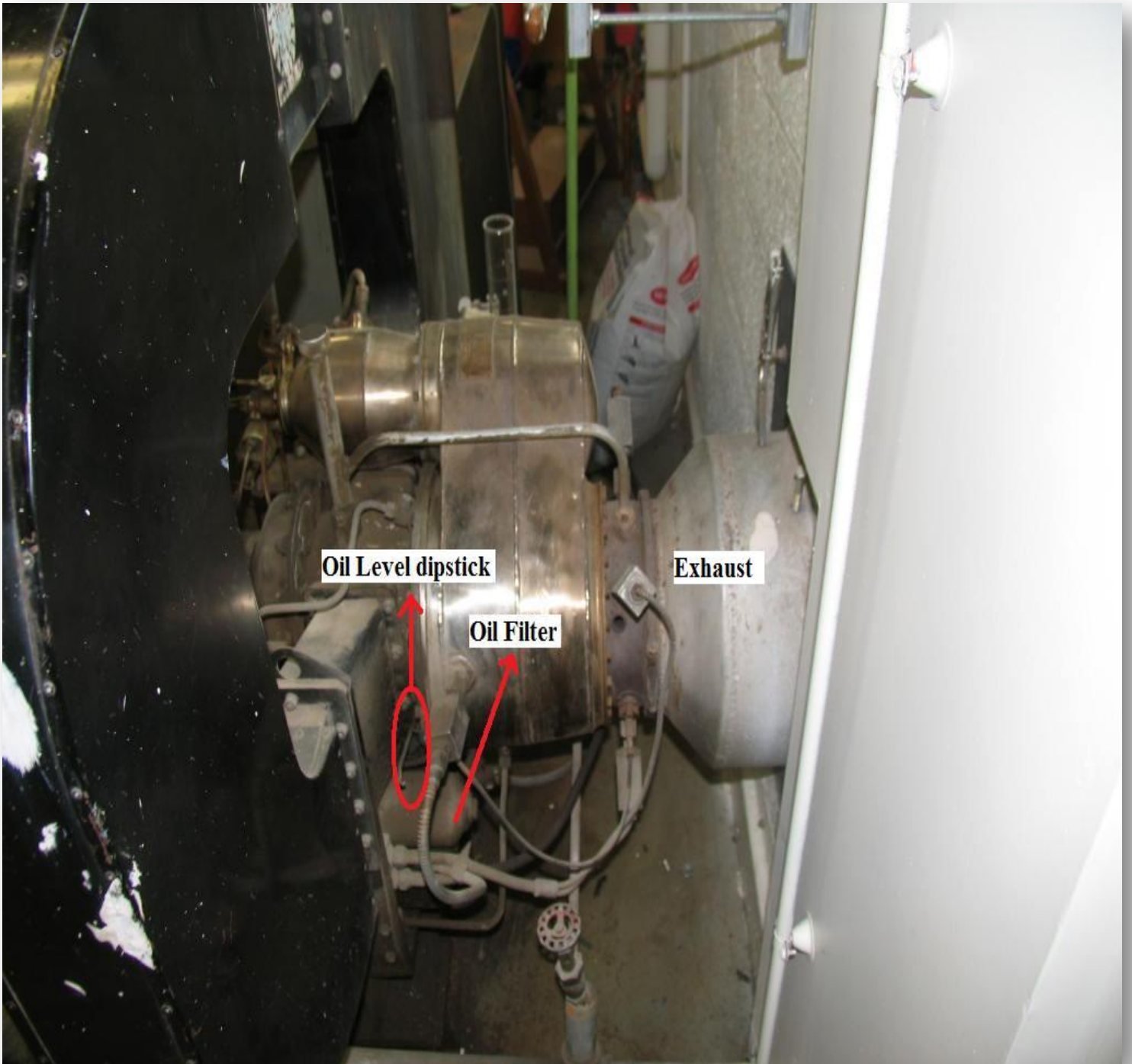


Figure 13: Apparatus components overview

The **oil filler tube** is situated at the top of the compressor housing together with the **breather pipe**.

3. Hazards and Controls Evaluation:-

3.1 Possible fire event

The Rover gas turbine apparatus is associated with high temperature gases and combustible fuel. There may be a fire event if the apparatus is not handled carefully and instructions are not followed. In the event of fire, evacuate the room immediately. Pull the nearest fire alarm (located outside room). Should you return to attempt to extinguish the fire, do not do so alone and make only one attempt. If unsuccessful then leave immediately. If successful stay at the scene and have someone alert Security (ph. # 4830) and Campus Safety (ph. # 5075). Please refer to Figure 1 (H-17 Head hall floor plan) to see the locations of fire extinguishers, fire alarm pull station and phone.

3.2 Ventilation

Ventilation fans and ductwork are installed such that there shall be fresh air introduced into the room (green duct) and ambient air exhausted from the room (teal duct) at all times that the room is occupied. These fans are controlled by wall switches locally (see Figure 14) but are on over-ride controls controlled by Facilities Management (FM). If at any time the fresh air supply or room exhaust fans are not working, contact FM immediately (ph # 4889). There is a household CO monitor mounted on the north pillar. Ensure that it is operational by observing the moving LCD display. Figure 14 displays the ventilation controls of H-17 lab.



Figure 14: Ventilation controls of room H-17

3.3 Kinetic, Thermal and Acoustic

The moving parts associated with the apparatus are the load adjusting wheel, static weight, weight adjusting wheel and the output pinion shaft on which the compressor and turbine are mounted. Load is applied on the IS/60 engine by turning the load adjusting wheel. It does not pose any serious kinetic threat if handled carefully. There is a meshed gear assembly underneath the load adjusting wheel to transmit the motion of wheel to the dynamometer. While turning the load adjusting wheel, be careful and keep the fingers of

your hands away from the meshed gears assembly as meshed gears are also rotating.

The applied load on the engine is balanced by a static weight, suspended by a spring (see figure 5). The weight adjusting wheel and the suspended static weight does not pose any kinetic threat if handled carefully during the operation.

The output pinion shaft connected to the dynamometer however poses serious threat. Body parts should be kept away from the shaft while the engine is running. The output pinion shaft is in safe casing but should be dealt carefully to avoid serious accidents. Also make sure that the shaft is clear of everything before operating the apparatus. Do not wear loose clothing and keep hairs tied back.

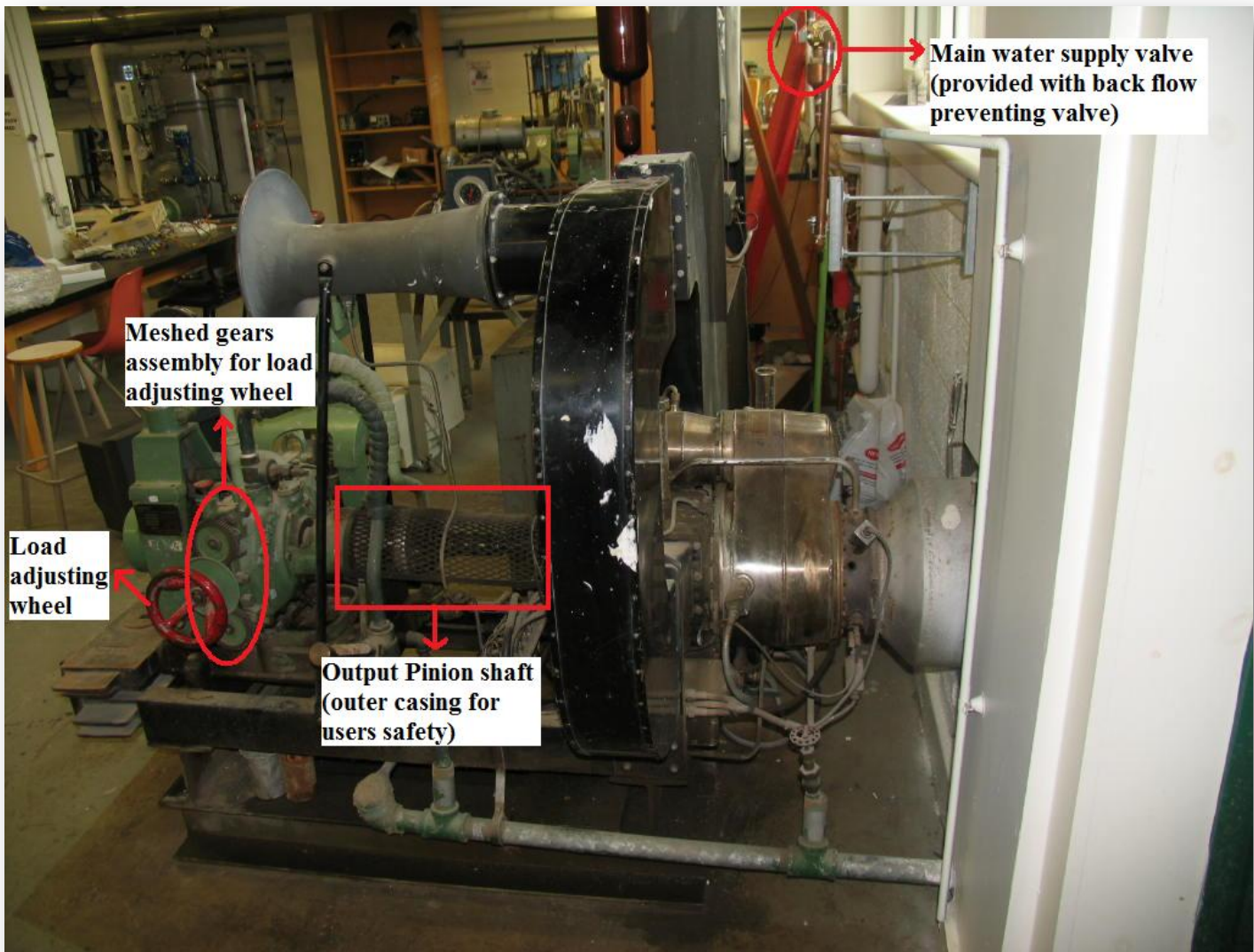


Figure 15: Moving parts of the apparatus

The apparatus is associated with very high temperatures. The combustion chamber and the engine exhaust are associated with very high temperature gases approximately 600°C-700°C. **Do not touch the main air casing, combustion chamber and engine exhaust while the engine is operating as they are an extreme thermal hazard.** There is no risk associated with the effluent gases since the exhaust ductwork is extended to the roof top and exhausted to the atmosphere.



Figure 16: Exhaust extension

The IS/60 engine is associated with high intensity sounds and is an acoustic hazard if ear plugs are not worn by the operator while engine is in operation.

(Wearing ear plugs is mandatory for the operator's safety)

3.4 Electrical

There is no electrical hazard associated with the apparatus if the apparatus is handled carefully and instructions are followed.

Be careful while connecting the starter box to the battery, as the starter box lead should be connected to **the negative terminal of the battery and the positive terminal of the battery is to be grounded**. If this is done otherwise then the starter box will spark and burn-out when the starter key is turned.

The fuel pump (for pumping fuel into the fuel tank at the top of control desk) is located at the bottom of the control desk (see Figure 8). It should be checked regularly for exposed or cut wires. Its power cord is located at the left rear of the control desk/panel. The thermocouple wires, that measure the exhaust gas temperature and the compressor delivery temperature, are insulated and do not pose any electric threat. The apparatus should be routinely checked for bare or cut electrical wires each time prior operation so as to avoid electrical hazards.

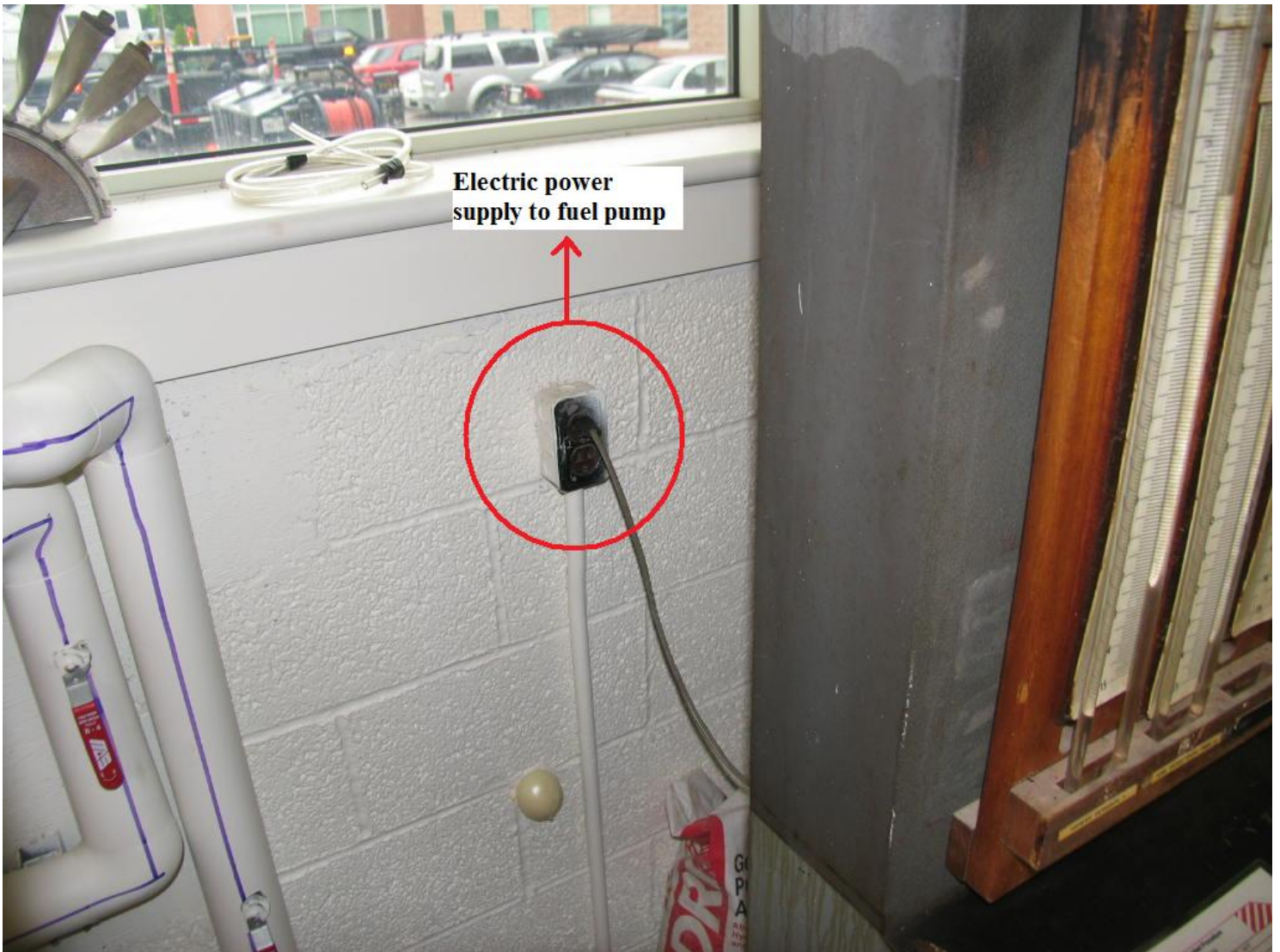


Figure 17: Electric outlet for fuel pump

3.5 Fuel and Water

The fuel source that is used is diesel. Diesel fuel is combustibile and reactive. The fuel is stored in the main fuel tank located outside the H-17 Lab. The fuel supply to the control desk fuel tank is controlled by the main fuel supply valve (see figure 20) and the fuel pump. The main fuel tank, fuel pipeline, control desk fuel tank and fuel pump should be checked for any leakage before proceeding with the experiment. Similarly, the pipeline carrying fuel to the engine from the control desk should be checked for any leakage before beginning the experiment. Any accumulated fuel, that has drained from the fuel drain assembly and the fuel accumulator mounted on the fuel burner,

should be collected by proper means to prevent fuel spillage. Diesel is combustible and exposure of spilled diesel to a spark can cause an ignition.

Water flow is supplied to the apparatus for the operation of the dynamometer and for the cooling of oil. A water/oil heat exchanger cools the oil. Water from the heat exchanger as well as the dynamometer is sent to water exhaust drain. Always make sure that water is flowing to drain. Water leakage or spillage is not very dangerous by itself, but should be avoided as water can cause electrical equipment failure. The pressure of the water entering the dynamometer is displayed on the water pressure indicator (see figure 4).

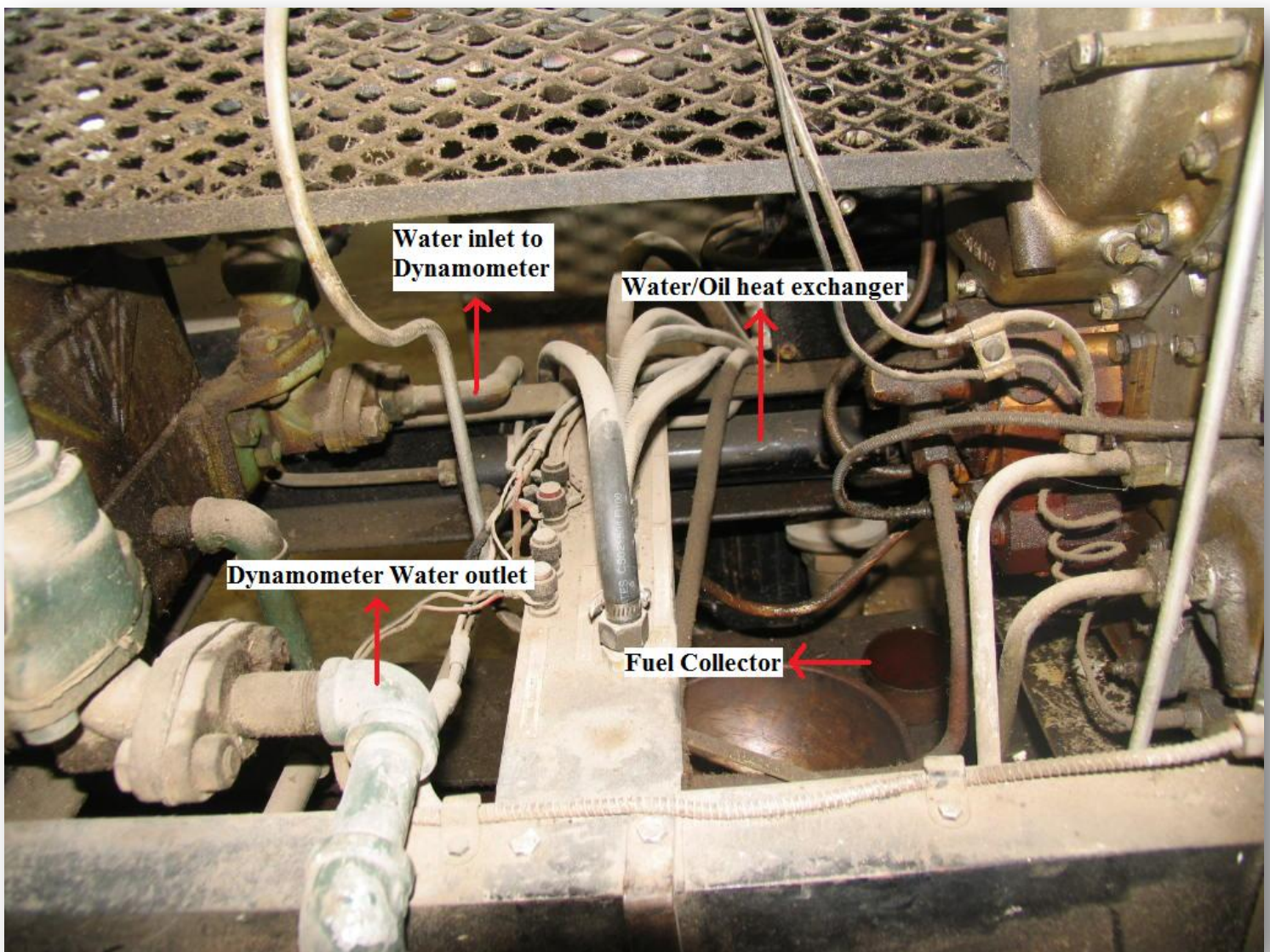


Figure 18: Fuel and Water



Figure 19: Main fuel tank location

3.6 General, physical and equipment concerns

The apparatus is associated with high pressures and very high temperatures. The gas turbine incorporates a temperature control as an overriding safeguard to high temperatures. This device consists of a temperature sensing tube that projects into the exhaust stream. It is connected by capillary tubing to the fuel control unit. Over-loading of the engine results in increased engine operating temperatures. Should the temperature rise above

the predetermined level, the temperature control automatically reduces the fuel supply to the fuel burner unit, until the temperature falls below the engine design limit. Excessive overheating of the engine results in a fuel supply termination and an automatic engine shut-down.



Figure 20: Main fuel supply valve location

The fuel control unit also has a mechanical governor to maintain the engine speed at 46,000 RPM. The mechanical governor is connected to a valve in the fuel control unit in such a way that a decrease or increase in the engine speed (caused by varying loads applied to the engine) results in a greater or lesser amount of fuel being supplied to the fuel burner. In do so it restores the speed to the correct parameter. If the engine RPM indicator is not accurate and shows incorrect RPM, then the RPM indicator should be

properly adjusted first rather than the mechanical governor. The majority of maintenance operations will be conducted using the RPM indicator, so this device should be checked regularly for proper operation.

3.7 Access

All personal in the H-17 laboratory should be preauthorized by the faculty in charge or under the supervision of authorized personal (lab technician or teacher assistant). No person other than the faculty supervisor in charge or specifically authorized personal are permitted to make alterations to, or to run experiments with the Rover gas turbine apparatus.

3.8 Training

All individuals using the apparatus shall be required to receive training in the proper operation and maintenance of the apparatus and its controls. Training will include such topics as the complete operation and control of the apparatus. Training programs shall be administered only by qualified personnel at UNB.

3.9 Personal Protective Equipment

Following personal protective equipment is required while using the apparatus:

- Ear plugs

4. Operation

4.1 Qualified Personal

These notes in the operation section will provide a guideline to the individual that has been trained by a qualified personal to operate the Rover Gas Turbine apparatus. Only after the individual has been trained and feels confident with the apparatus operation and shutdown procedures should he or she attempt to operate the apparatus using these notes. Do not proceed if you are not properly trained or are unsure in any manner of the safe operation of the apparatus and its associated safety concerns.

4.2 Experiment Preparation/Startup

Following steps should be carried out to prepare for the experiment:

- Ensure that the fuel drain assembly (See figure 7) is not faulty and that the apparatus is not inclined upwards at the exhaust end, so that complete fuel drainage is not impaired. If fuel drainage is affected, then there is a possibility of engine over speeding at start-up due to a large amount of residual fuel accumulation in the combustion chamber or main air casing. Fuel may be present after a failed engine start-up. The fuel might also accumulate due to a slight leak at the fuel burner. This accumulated fuel produces an over rich air/fuel mixture during the engine start-up period. Dangerous conditions can result if the amount of accumulated fuel is excessive. The engine might accelerate to an unduly high speed and temperature at start-up. Before starting the apparatus, unscrew the fuel drain valve and replace it after all the fuel in the main air casing has drained. A defective fuel drain assembly should be rectified and replaced immediately.
- Ensure that the engine is free of load (check that the dynamometer hand wheel is closed). The engine should not be started with a load already applied to it.
- Ensure that the main fuel supply valve (see figure 20) is open and that the fuel pump is switched on and is actively pumping fuel to the fuel tank, located at the top of the apparatus. The apparatus fuel tank should be full before commencing the experiment.
- Turn on the fuel control knob on the control desk so that the fuel measuring flask is full of fuel. Then shut-off the fuel supply by turning the fuel control knob to off.
- Unscrew the fuel accumulator a few turns to release already accumulated fuel and allow air to enter the accumulator bulb. Then screw the fuel accumulator down until it is finger tight.

- Ensure that the air intakes are clean and clear.
- Turn on the water supply by opening the main water supply valve. The water pressure should be 15 psi minimum for oil cooling and can be checked by the water pressure indicator on the apparatus. Open the water flow to the apparatus 15 minutes prior to starting the experiment so that the water is at a constant room temperature (21°C). Also ensure that the water used by the apparatus for the cooling of oil and for the dynamometer is properly draining.
- Set the throttle lever on the control desk to the 1/2 way position.

4.3 Lab Instructions

4.3.1 Instructor Responsibilities

The Standard Operating Procedure for the apparatus shall be reviewed and well comprehended. This document provides all the necessary information regarding the apparatus startup procedure, operation, hazards involved & safety precautions to be taken while using this apparatus. The lab instructor shall remain in the room while the experiment is in progress. When the entire student group has assembled, and before any explanation has begun, the instructor shall relay all safety precautions and hazards as outlined in section 3. Inform all students that they must contact the instructor, should any problems or concerns arise during the experiment. Make the group aware of the fire extinguisher locations, fire alarm pull stations, phone and exits. Any student from the group missing the required personal protective equipment shall not be allowed by the instructor to enter the laboratory H-17 and to proceed with the experiment.

4.3.2 Data/Instruments Locations and Functions

Please refer to Figure 21 to see the location of data display units and their functions:

- Compressor delivery pressure gauge - (displays the pressure of gases delivered to the compressor).
- Compressor delivery temperature gauge - (displays the temperature of gases delivered to the compressor).

- Exhaust gases temperature indicator - (displays the temperature of exhaust gases leaving the exhaust).
- Impeller tip pressure gauge – (displays the compressor impeller tip pressure).
- Turbine inlet pressure manometer – (displays the pressure of gases entering the turbine).
- Turbine outlet pressure manometer – (display the pressure of gases leaving the turbine).
- Airmeter depression manometer – (displays the pressure drop across the airmeter venturi).

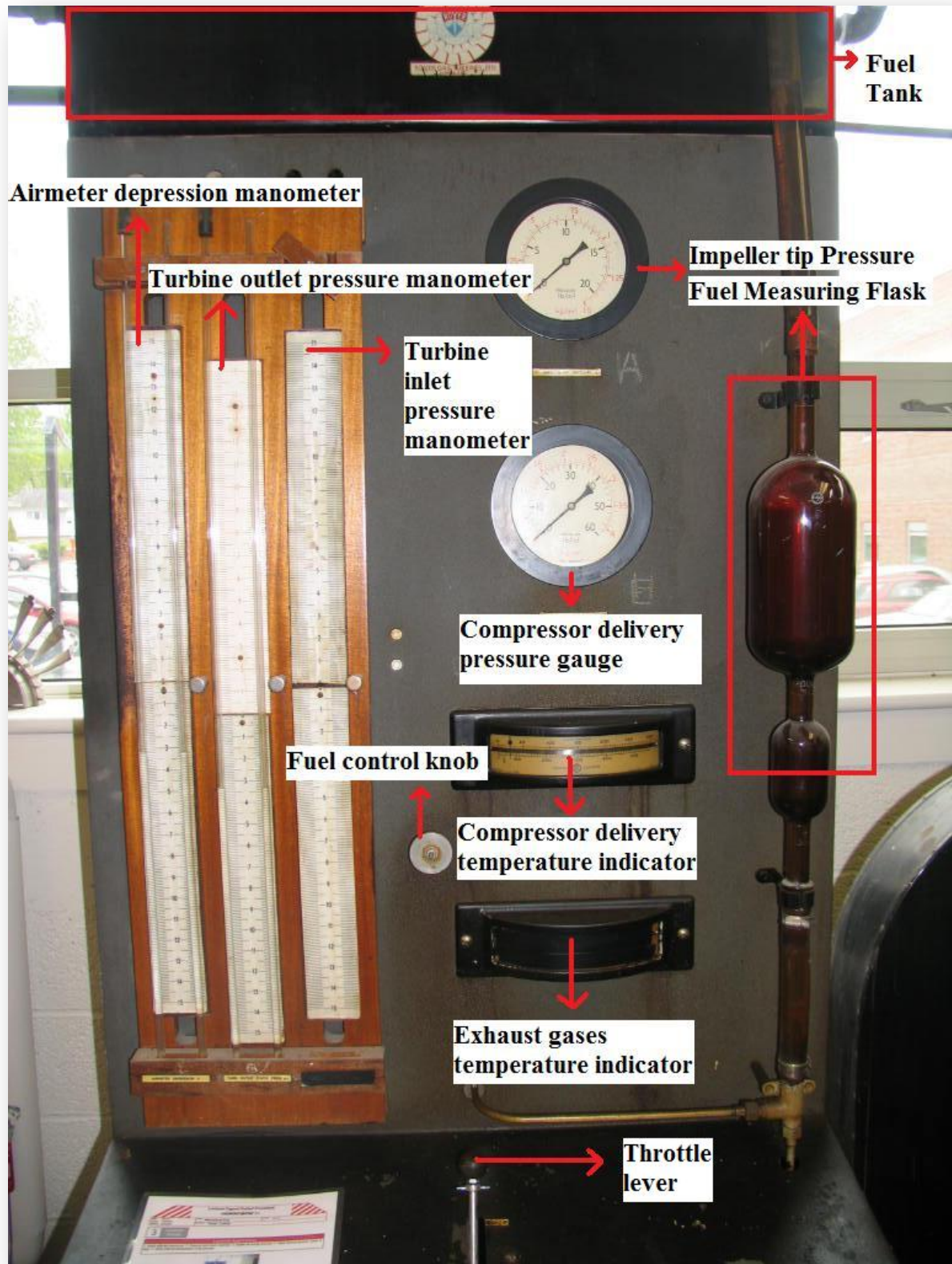


Figure 21: Data locations and functions

4.4 Operating Procedure

4.4.1 Experiment procedure

After preparing for the experiment and following all the steps mentioned in section 4.2 to prepare for this experiment, follow the following steps to complete the experiment:

- With the fuel operating lever (mounted on the fuel burner) in the closed position, turn the starter motor switch key clockwise through 60° (i.e. to Position 3) and hold against spring pressure when starter motor is operating. Once the engine starts then the key will return back to position 2.

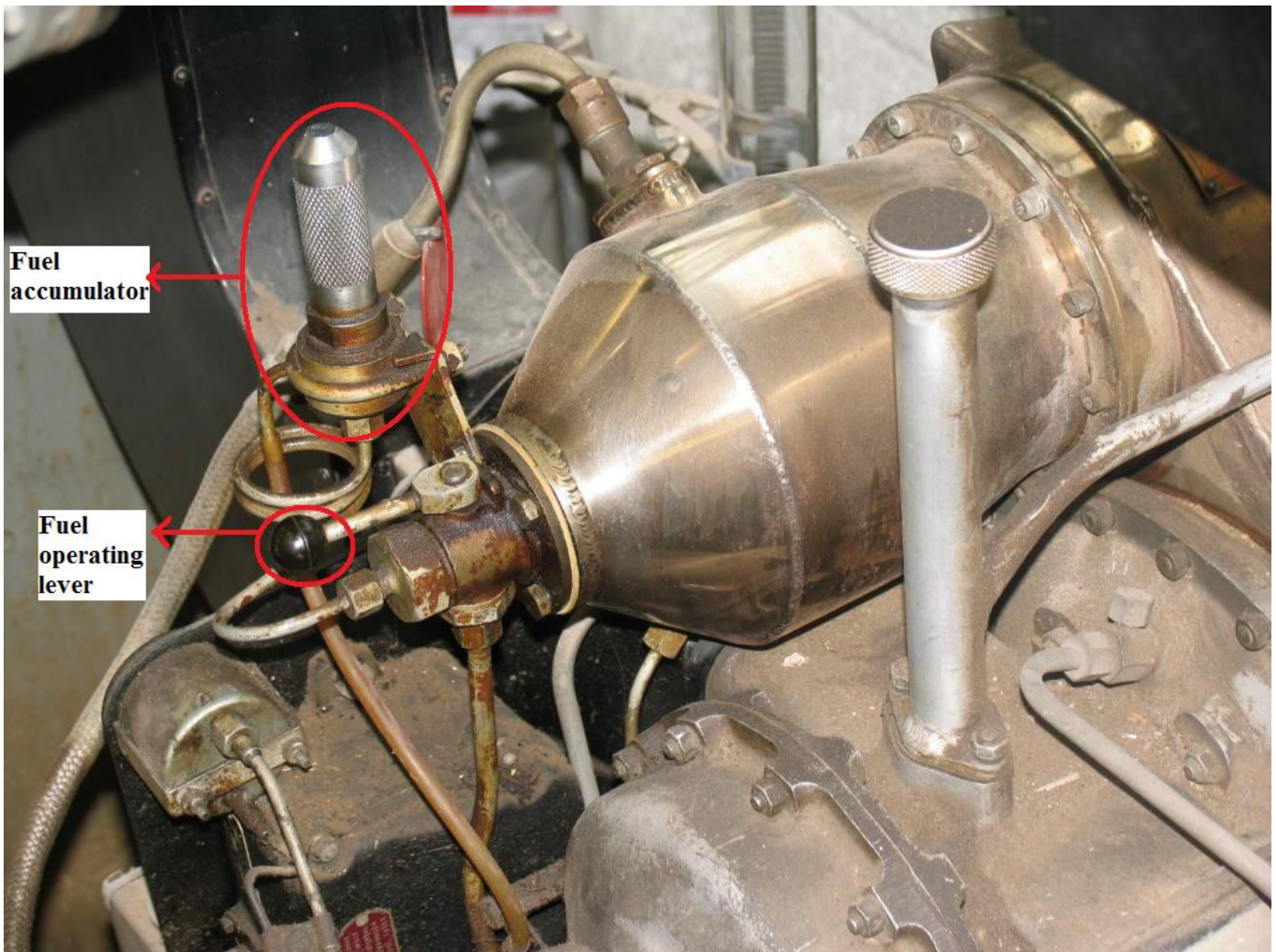


Figure 22: Fuel burner assembly

- When the engine speed reaches a constant ≈ 400 RPM on the tachometer (RPM indicator), open the fuel burner (atomizer) by turning the fuel operating lever and the engine will fire up. The combustion of air in the combustion chamber will be indicated by the “ROARING” of the engine.
- At approximately 2500 RPM, after the cut-out switch has disconnected the starter motor, turn the starter key to “OFF” and remove the key.
- When the engine reaches a steady speed, check the following:
 - a. Engine speed is not appreciably over 2500 RPM.
 - b. Oil pressure is at least 7 Psi and temperature is less than 110°C.
 If conditions of either ‘a’ & ‘b’ are not satisfied then immediately shut down the apparatus and abort the experiment. Notify the lab technician about the problem so that the cause can be investigated.
- Gradually set the control desk engine throttle lever from the 1/2 way position to obtain the desired speed (RPM).
- Load the dynamometer as required to obtain different readings for the experiment. When the engine is loaded its RPM decreases, so balance the load with the hanging static weight to keep RPM constant. Use the control desk throttle lever to increase the RPM of the engine.
(an increased RPM increases fuel consumption of the engine)

4.4.2 Normal Shutdown

Follow this procedure to shut down the gas turbine apparatus:

- Remove the dynamometer load and ensure there is no load on the engine.
- Move the control desk throttle lever to shut off position.
- Shut off the fuel burner (atomizer) by turning the fuel operating lever.

- Turn off the fuel pump.
- Turn off the main fuel supply valve (see figure 20) and the control desk fuel control knob.
- Turn off the water supply to the apparatus by turning the main water supply valve OFF.
- Before leaving the lab, ensure that there are no objects left on the apparatus. Clean the apparatus with a piece of cloth.

4.4.3 Emergency Shutdown

Follow the following procedure in given order to shut down the gas turbine apparatus in case of emergency:

1. Shut off the fuel burner (atomizer) by turning the fuel operating lever.
2. Move the control desk throttle lever to shut off position.
3. Turn off the fuel pump.
4. Turn off the main fuel supply valve (see figure 20) and the control desk fuel control knob.
5. Turn off the water supply to the apparatus by turning the main water supply valve OFF.
6. Remove the dynamometer load and ensure there is no load on the engine.
7. Before leaving the lab, ensure that there are no objects left on the apparatus. Clean the apparatus with a piece of cloth.
8. Notify instructor of any problems or reasons that the experiment was terminated.

5.0 Inspection

Inspections at regular intervals shall be performed on the apparatus to ensure that the apparatus is kept in a safe and well maintained condition. The inspection includes the observation of any cracks in main fuel tank, control desk fuel tank, fuel & water pipe line, leaks in combustion chamber and engine exhaust and a routine check for bare & cut electrical wires in the apparatus.

5.1 Periodic & Operational Inspections

Visual inspections are the responsibility of the person who is conducting experiments on a regular basis with the Rover Gas Turbine apparatus and should be carried out each time before operating the apparatus. A complete periodic inspection of the apparatus shall be performed by the person who is conducting experiments on a regular basis with this apparatus. That same person will alert the faculty supervisor of any deficiencies in the apparatus. The deficiencies such as those listed below shall be examined during both the periodic & operational inspection. The faculty supervisor will determine if the deficiencies will affect the safe operation of the apparatus.

- a. Function, temperature and pressure displays and warning labels.
- b. Worn, cut or bare electrical wires.
- c. Cracked fuel tank, fuel & water pipeline leaks and worn or corroded pipes.
- d. Pierced pipes and leaks in the main air casing, exhaust and combustion chamber.

6.0 Typical Tests

The actual test procedure will be outlined in the lab script as issued by the professor (faculty supervisor). A typical test includes the calculation of Brake horse power, Thermal efficiency, Fuel consumption, Brake specific fuel consumption, Air/fuel ratio, percent excess air and compressor pressure ratio. Please refer to Appendix 'A' to see the detailed lab script, sample calculations and experiment results.

Appendix 'A'

Appendix 'B'

Appendix 'C'

Appendix 'D'

Appendix 'E'

