Thinking out-of-the-box...

The MULTI-ENGINE TEST CELL FACILITY for Kenyan Navy is the first of it's kind design for such challenging applications. Neptunus achieved an engineering breakthrough leading to a uniquely versatile, efficient and economical infrastructure for the customer.

A design application paper by
Neptunus Power Plant Services Pvt. Ltd.

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NEPTUNUS
The Machine Reliability Expert

www.neptunus-power.com

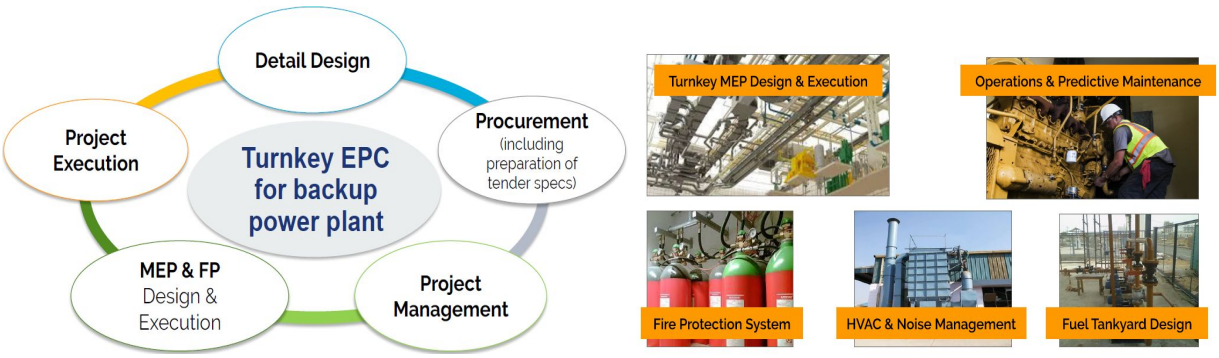
Context

- Kenyan Navy headquartered at Mombasa, Kenya has an operating history of 55 years. Like any other navy, the Kenyan Navy vessels are powered by diesel engines of different makes and capacities. These engines must comply to the stringent military grade performance standards.
- Kenyan Navy desired to upgrade and retrofit their existing PaxmanV16 engine test cell at Mombasa, Kenya to facilitate load testing and validation of five (5) of their marine engines namely PaxmanV16, PaxmanV18, MTU956, MTU362 and MTU4000.
- Neptunus Power Plant Services Pvt Ltd was awarded the contract to design and build the test bench engineering system in Mombasa, Kenya.
- Neptunus with over 23 years of experience in diesel/ gas engines and expertise in engineering solutions was trusted with this challenging assignment to design and build the test bench for Kenyan Navy.

About Neptunus Power Plant Services Pvt. Ltd.

Neptunus leverages 23 years of experience in complete engine lifecycle management services which include designing of diesel/ gas engine based system to installation, operations, maintenance and overhauling including supply of spares. With the reliability-centric design, execution, and management of the project, we enable sustained value creation over the operational life of the facility. In short, **we deliver the design that works.**

Our services



First of it's kind unique design & development of a Multi-engine Test Cell facility by Neptunus

Executive Summary

This application paper familiarizes the readers with the challenges involved in the design of a single test bench facility and its auxiliaries to equip five marine engines of different rpms, power capacities and make to perform the load tests and engine diagnostics.

The challenges involved were muti-dimensional including the large variation in the size, capacities and design of the engines, need for complex structural and mechanical simulations, addressing the environmental concerns to name a few.

This document covers the general considerations, design challenges and solutions of a low cost, multi-engine, multi-power, multi brand test bench. This is an overview and does not include a list of all the components necessary for the construction and operation of such a test cell.

Introduction to engine test bench

An engine test bench is used to test and validate engine parameters such as power, fuel consumption, vibration, noise, crankshaft torque, angular velocity, pollutant concentrations in the exhaust gas, exhaust gas temperature, engine oil temperature and intake manifold pressure mainly after the major overhaul.

It houses sensors (transducers), data acquisition features and actuators to control the engine state. Major components of the test bench facility are Hydraulic variable fill resistive type dynamometer, common base frame for engine and dyno, engine water and dyno water cooling systems with radiators, fuel, lube, outlet exhaust and inlet air systems, instrument and power control console.

Dyno is a device for measuring force, moment of force (torque), power, rotational speed (rpm) produced by an engine, motor and other rotating prime movers. Engine-dyno base frame shall hold and arrest its own vibrations during the testing without transfer to the engine or to the engine room.

Fuel tanks, lube oil sumps, air inlet sumps and its associated systems are designed with filtration and instrumentation to supply fuel for the combustion of engines, lube for cooling the engine components, compressed air for the engine starting motor and cylinders respectively.

Cooling system of the engine and dyno are equipped with radiators for effective heat load management. These open environment radiators are equipped with propeller fans controlled by programmable logic control (PLC). Engine rpm, start/stop for testing can also be controlled from the same PLC.

Design Framework

The subject case study involved design & development of a “common” test bench for following multiple engine types used by the Kenyan Navy vessels.

ENGINE Make & Model	Power (kW)	Brake Horsepower (bhp)	Maximum RPM	Fuel consumption (g/s)
Paxman V16	2014	2700	1500	126
Paxman V18	2268	4545	1500	141
MTU 956	3200	4500	1575	238
MTU 362	992	1331	1500	60
MTU 4000 (Planned)	3440	4613	2100	213.8

- Engine test bench designed is capable of dealing with energy flows (Fuel, air, lube, cooling water) that are three times greater than the ‘headline’ engine rating. Room acoustics, forced ventilation of engine room, compressed air system for engine starting systems are provided in this test cell facility.
- Recirculation and filtration systems provided in the water, fuel and lube oil systems maintain the quality of the systems at required levels at all the stages of the operation. Alfa Laval fuel filtration is provided in the fuel line for effective sludge removal.
- PLC direct communication with the field and engine sensors is established. Accurate engine speed regulation through Woodward 2301A speed controller for electric actuators, pneumatic control via PLC or through geared motor for hydra-mechanical governors is established.

Design Challenges

While it's common to design a test cell dedicated to a single type an engine, there is no reference standard available to design a single common test cell to handle multiple capacity & specification engines. This fact posed some unique challenges that were overcome by the Neptunus team with cooperation of the customer and other stakeholders. The key challenges are listed below;

- The varying height and size of different engines to be tested posed design & fabrication challenge to make a single base frame to enable engine shafts and dyno shaft alignment (shafts centre line match).
- The varying diameter of the shaft as per the engine type posed design & fabrication challenge to make the coupling between the engine and dyno shafts.
- Increase in dyno water temperature beyond 40˚C could lead to the operational complications. This posed a challenge to design the dyno cooling circuit to match the typical flow rates of the engines along with temperature control at all the working conditions.
- The design of the exhaust duct was a challenge because of limitations on available space and the varying dimensions, height & location of the outlet of exhaust of five engines w.r.t. Ground level.
- The variation in the inlet and outlet sizes and locations of the different engine types posed design & construction challenges in the water, fuel, lube, inlet air connections of the test bench facility.
- Management of the quantity, temperature, pressure and quality of the following common circuits were a design challenge - Lube system for efficient engine cooling, fuel system for efficient fuel consumption, fuel-air mixture, Air supply system for engine starting motors and cylinders, Exhaust trunking (pipe) to match to the exhaust connections of all the five engines to enable acceptable back pressure on the engine, cooling water system and radiators for efficient heat dissipation

Neptunus' Innovative Design Approach

The following is a summary of the innovative design approach taken by Neptunus in each system of the test bench facility in consideration of the challenges described earlier arising from the unique requirement of designing a single test bench facility and its auxiliaries to equip five marine engines of different rpms, power capacities and make to perform the load tests and engine diagnostics.

1. **DYNO**

Pre-existing dyno (Paxman V16 supportable) was refurbished by Neptunus at Froude Inc. UK to be able to make it capable of testing five engines with four zones of the power and torque capacity curves correctly. Neptunus incorporated following critical changes in dyno design along with the power and torque curve selection;

- Provided rotachocks against shims on the dyno base frame for height adjustment for shaft's alignment.
- Designed, fabricated and validated five different couplings to couple the shafts of dyno and five different engine types to be tested.
- To manage the differences in the shaft diameter of each engine type and the dyno shaft diameter, a Butterfly valve was designed and provided over the oil pump of dyno for manual alteration of pressure according to the requirement (engine, operating condition)
- Auto control of the water inlet and outlet valves of dyno was obtained by the use of a temperature sensor at the water outlet, which shall adjust both the valves to maintain the water temperature inside the dyno in the range of 25-60°C.

2. BASE FRAME

- Engine-dyno shaft centre line mismatch for all the engines is explained in Figure-3. The figure indicates the relative height of the engines' shaft centre line against the dyno shaft centre without additional height adjustment tools.
- Base frame has been designed to accommodate engines of different widths through the brackets for sturdy fitment as explained in Figure-4. The figure indicates the relative width of all the engines having deep sump with all of them fitted to the base frame.
- Five different stools were custom designed with brackets on it at common and typical locations for sturdy fitment on the base frame. Stools are placed over the base frame for height adjustment to match the centreline of engine shaft with dyno shaft.

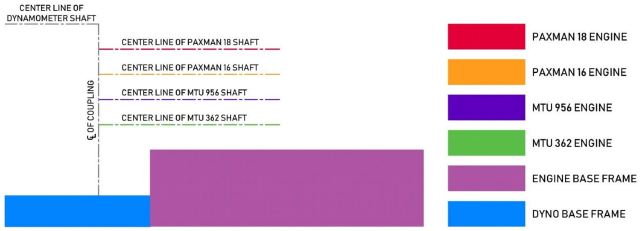


Figure-3 Engine-Dyno shafts relative height representation

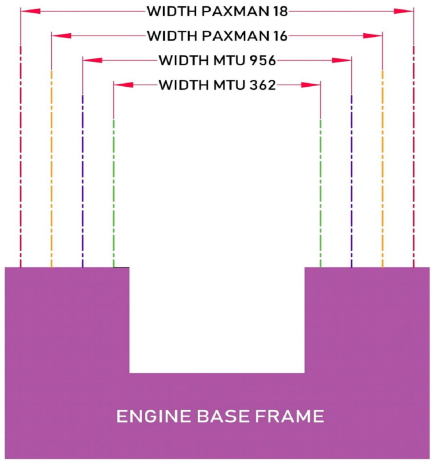


Figure-4 Engines width representation

3. COOLING SYSTEM:

Marine engines are cooled with seawater directly or indirectly. Cooling system of the subject test bench facility has been built to accommodate the marine engines and dyno contain HT (High Temperature), LT (Low Temperature), dyno water circuits through thermostats, dyno radiators, LT radiators, HT radiators.

Wastewater shall be stored, filtered and reused. The cooling system of the dyno has also been designed with radiators, auto controlled servo valves in the outlet and the inlet of the dyno water circuit controlled by thermostats. Dedicated radiators controlled by PLC shall operate the cooling circuit according to the requirement of the respective engines.

4. FUEL SYSTEM

Fuel system contains the pumps (booster and transfer), PRVs for heat exchangers in the return fuel line, filtration system with visco mass type flow meter, along with the necessary valves.
As the location, pressure, flow and the diameter of fuel inlet pipe are typical for every engine, custom designed flexible pipelines and hose flanges were designed & fabricated to serve every specific engine.

5. COMPRESSED AIR SYSTEM:

Supply of compressed air to starting motors is the method of starting of MTU 362, Paxman V16, MTU 4000, Paxman V18 engines. Whereas, supply of compressed air directly to the engine cylinders is the starting method for MTU 956 engine. It was quite complex to design a compressed air circuit to supply clean air to engine starting motors, engine cylinders, MIP unit of the Paxman V18 engine, Dyno bearings at regulated flow and pressure.

Neptunus has provided the following in the circuit to accommodate the above-mentioned requirements and provide the compressed air at controlled flow and pressure.

- Pressure switch provided on the dual stage compressor for manual control of outlet pressure to equip all the engines with the required pressure.

- Air regulator provided for the control of the inlet pressure of dyno bearings to support the functioning of dyno for the operation of all the engines.

6. EXHAUST TRUNKING:

It has been a spatial and complex challenge to design the exhaust trunking to suit the requirements of all the five engines. Moreover, Paxman engines contain two individual exhaust discharge pipes from engine whereas MTU engines have a single discharge duct pipe. Diameter, height and the location of the exhaust duct is typical for every engine.

Neptunus designed a common exhaust ducting system to support all the five engines. The exhaust from the engines is designed to be connected to a common connection adapter that houses flanges suitable for inlet connections of all the engines and outlet connection suitable for the MTU4000 (highest load) engine.

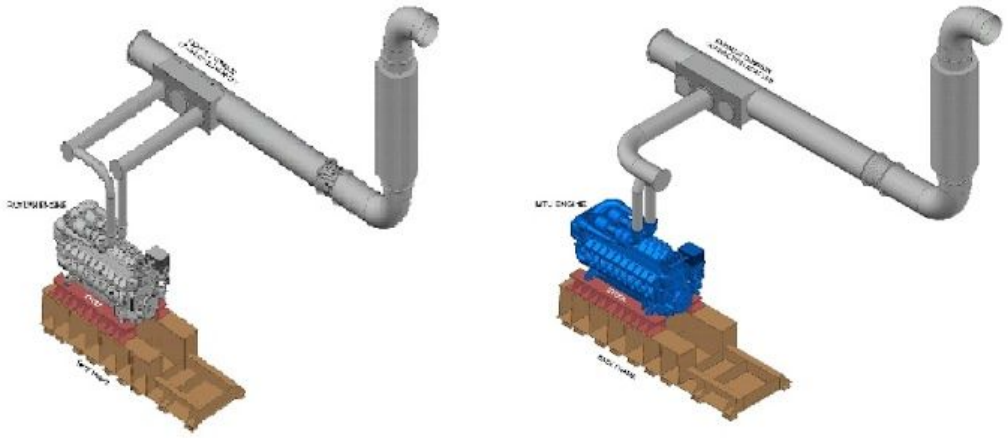


Figure 5: Exhaust trunking for Paxman V16 & V18 (left) and MTU 956 & 362 (right)

7. INSTRUMENTATION AND CONTROL

The instrumentation and control system of this test cell consists of the SCADA (Supervisory control and data acquisition), PLC , Motor Control Console (MCC) , and UPS. Data loss and operational discrepancy are predicted as the risks of the system and the instrumentation of dyno, test bench auxiliaries are chosen to nullify these risks.

- Bypass lines and redundant components are introduced at necessary locations in all the circuits to avoid operation discrepancy during instrumentation failure
- For all the sensors that communicate directly with PLC, parameters shall be recorded in SCADA.
- Remote controlled loading is enabled in the retrofitted dyno design against the pre-existing manual loading through control switch notch for fast and accurate engine testing.
- To avoid overload on the motor drives during testing, overload protection through the dedicated and backup MPCB (Motor protection control board) overload relays are provided in the system.

8. MINIMIZING THE ENVIRONMENTAL IMPACT - GREEN TEST CELL DESIGN

Neptunus paid conscience attention in design to minimize the adverse impact on the environment and endeavoured to build green test cell by incorporating following design elements;

- Europafilter offline kidney loop filtration system incorporated to purify the lube oil upto 0.1microns. It is a general practice to discard lube oil after the engine test. However in this test cell system, oil shall be completly filtered and reused multiple times. The filter inserts used are of biodegradable type.
- Use of radiators to replace cooling towers.
- Wastewater recirculation and purification system in the dyno, HT and LT circuits. Even in the case of engine replacement over the base frame, water is designed to be drained into the sump, which will always be reused completely.

- Design of the exhaust system with zero downwash to protect the environment and maintain air quality at required safe breathing levels.

Design Validation

BASE FRAME:

- The structural stability of the base frame is validated with the structural analysis software; SESAM Genie V 7.1-12 and it was verified that stress on base frame is within the allowable limit.
- Fabricated base frame's ability to hold the dynamic load and vibration of engines is successfully validated at the site (Mombasa, Kenya, Africa).

EXHAUST:

The selection of the exhaust duct size, velocity of the exhaust in the pipe, back-pressure on the engine is validated with the theoretical calculations.

The selection is validated with the velocity simulation through ANSYS and plume rise analysis simulation through AERMOD software.

AERMOD analysis confirmed that the dispersion of exhaust is within the acceptable limits of the local environmental norms and is proven to have negligible effect on the residential complex of Mombasa, Kenya located at around 5 Kilometres from it.

Summary

Neptunus has successfully designed, fabricated, erected, commissioned and validated the test cell facility to accommodate Paxman V16, Paxman V18, MTU 362 and MTU 956. Neptunus has also custom designed the sub-systems of this test cell facility like stools, couplings, hose flanges, exhaust common adaptor plates, circuit orifices etc. to equip this test cell for testing of MTU4000 engine.

Neptunus endeavours to build challenging, complicated, green, custom designed test cells for testing and validation of engines with the same spirit in future.

In the case of queries, kindly contact the below mentioned at the provided phone numbers. We would like to hear from you, share experiences with you to better the way test cells are built.

Why Neptunus

At Neptunus, we believe that there is a better way to operate and maintain critical assets. We have more than 23 years of experience in operations and maintenance of diesel engines and other large rotating machinery. We also specialize in deploying Advanced Predictive Maintenance solutions. This allows us to solve critical engineering problems of our customers, adding value by saving them costs and giving them high equipment reliability.

We undertake a complete EPC package comprising of the backup power plant, associated fuel storage & management, HVAC, MEP along with the Fire Protection System. Having full life cycle experience also gives us an edge in procurement, since we're able to evaluate Capex v/s Opex trade-offs.

We have successfully designed and delivered many greenfield/brownfield projects for industrial, commercial, marine and defense establishments in India and globally.

Types of assignments undertaken by Neptunus:

- EPC of diesel and gas engine based backup power units for mission-critical applications like Data Centers - we do both, greenfield (new) as well as brownfield (Refurbishment, Rebuilding, Repowering, Shifting of existing units) projects.
- Other commercial and industrial Captive Power Plants for Cold Storage Units, Life Science Centers, Hospitals, Blood Banks, Civic Utilities, etc.
- Offshore and Land Oil Rigs, platform supply vessels
- Building diesel engine test cells above 250 kVA, with an option for multi-make/ multi-model engine test cells, which is a unique ability possessed by Neptunus.
- Mechanical, Electrical, Plumbing, Fire system, HVAC & heavy piping Projects such as Industrial infrastructure, commercial facilities or high-end residential buildings.
- Turnkey project management consultancy.
- Waste to Power (WTE) Projects.

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