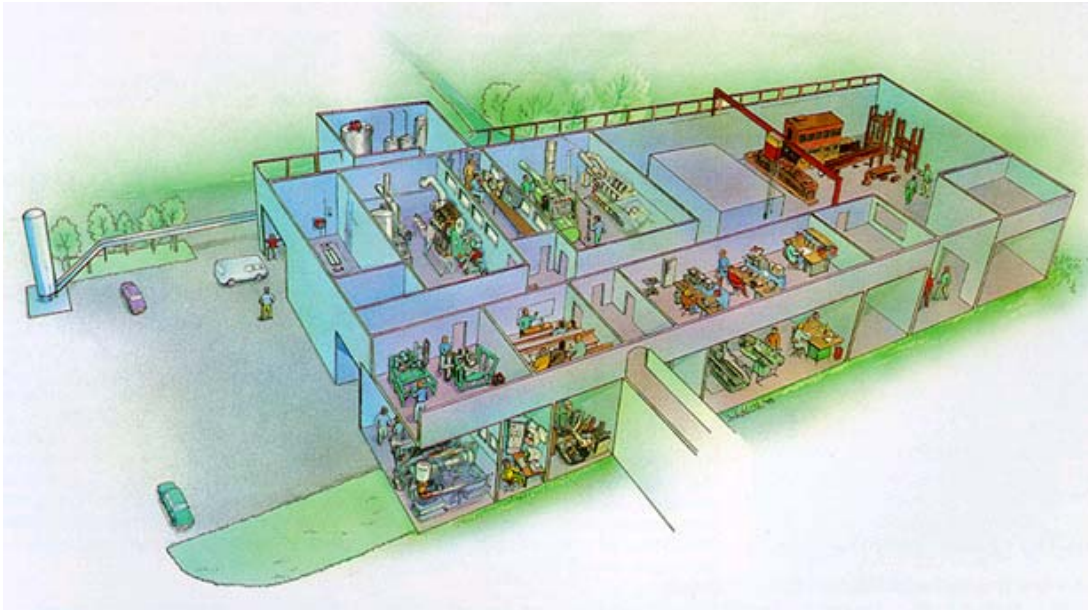


Gas Motor Technology Laboratory

- At NTNU Marine Technology and SINTEF MARINTEK

The Gas Motor Technology Laboratory (GMT-LAB) comprises a main hall and eight test cells for testing of large and small products. The main hall has a maximum ceiling height of 12.5 m, and is equipped with 5 and 10 tonnes overhead cranes. Several workshops, a boiler house, an oil treatment room and test cells for fixed-installation engines and temporary installations are all located in the laboratory.



The GMT-LAB is equipped for product verification, testing and development for marine and land-based industries. Typical examples of work carried out include:

- Functional testing
- Verification
- Accelerated testing
- Testing of ability to with-stand such factors as cold, heat, pressure, mechanical abuse, vibration, humidity, etc.

In close co-operation with product developers and suppliers, NTNU carries out tests that contribute to:

- Better awareness of products' potential and limitations
- Providing data required for product improvement
- Providing data required for product documentation

The GMT-LAB has a flexible infrastructure and its personnel all have solid experience in the fields of applied measurement techniques and mechanical engineering. This means that tests can be performed on a wide range of products without wide-ranging and expensive modifications having to be made.

Diesel and gas engines

Bergen Diesel KR3 (diesel and gas)

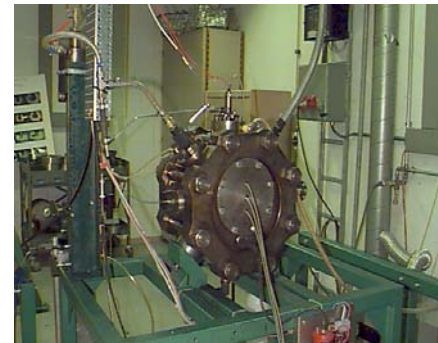
- Ulstein Bergen B engine (diesel and gas)
- Vasa 32 (diesel and gas)
- Wichmann1 DM (diesel)
- Scania DS11 engine (diesel)
- Motor vehicle engines (petrol and diesel)

As well as the fixed engine installations, four general test-beds for diesel/petrol/gas engines in the range of 10-1000 kW.



Test rigs

Rigs for testing combustion characteristics of gas, fuel and petrol. Wear measurement rig for fuel injection equipment (pumps and nozzles).



Auxiliary systems

Fuel oil supply

Pre-treatment equipment, storage tanks, pumps and pipelines for heavy oil, diesel oil and petrol.

Fuel gas system

30 m³ LNG tank, 2 m³ LPG tank, high-pressure LNG system for pressures up to 400 bar. Inline mixing of gas to get desired natural gas quality. In addition a mixed-gas system for manual mixing of gases in gas cylinders is available.

Steam boiler

Our steam boiler has a capacity of 1,500 kg per hour. Steam lines are installed throughout the laboratory.



Compressed air

Compressors for working air, start air (15m³, 25 bar) and instrument air distributed throughout the laboratory.

Cooling water system

50,000 m³ cooling basin, cooling tower, pumps and pipelines to individual test installations.

Major research and development projects

Department of Marine Engineering covers the field of internal combustion engines in general, with emphasis on marine diesel engines.

Our teaching covers engine performance in general, engine process analysis including combustion, exhaust emissions and turbo-charging, and internal mechanical and thermal loads in the engine.

The research in the field of internal combustion engines has covered several important problem areas. The following list that sums up our research activities (in chronological order) are provided as indication of our activities.

- The engine drive train including crank mechanism, bearing loads, hydrodynamic bearing load capacity. Torsional vibrations in shaft systems. Inlet and exhaust valve mechanisms including cam design.
- Thermal loading of engine components. Development of methods for theoretical analysis of temperature fields and combined thermal- and mechanical stresses and deformations. Experimental techniques for measurement of temperature in engine components.
- Utilisation of heavy fuel oils in diesel engine. Investigation of ignition properties of diesel fuels. Development of constant volume pressurised combustion chamber for study of fuel injection and (thermal) auto ignition.
- Theoretical models of in-cylinder engine processes. Analysis of heat release based on cylinder pressure measurements, including methods for identification of systematic errors and correction of such errors. Development of engine performance simulation models based on first principles.
- Engines exhaust emission measurements. Fuel quality evaluation for spark ignited engines and diesel engines. Fuel quality influence on combustion variability and exhaust emissions.
- Utilisation of gaseous fuels in internal combustion engines. Spark ignition quality of pure gaseous fuels and gas mixtures. Development of optical methods for visualisation of ignition and flame kernel development.
- Gas injection at high pressure: study of the development of high-pressure gas jets by theoretical CFD methods including chemical kinetics, and optical experimental methods. Study of thermal auto ignition in high-pressure gas jets. Ignition improvement by means of hot surfaces.

- Environmental friendly diesel engines. Various aspects of reducing exhaust emissions from marine diesel engines, including engine optimisation by adjustments and simple modifications, and improved combustion control. The project was also concerned with theoretical and experimental analysis of fuel injection and spray development. A major part of the project dealt with theoretical computations. CFD-methods, based on the KIVA-II code, were developed for computation of turbulent 3-D spray development, ignition and combustion in marine diesel engines. Computations were demonstrated for medium speed and slow speed engines.
- System modelling and simulation. The project was concerned with generic methods for developing models of dynamic processes and dynamic systems. Applications covered several machinery systems, including performance modelling of gas-fuelled engines and diesel engines.
- Development of Lean Burn Gas engines, medium and high speed. Combustion systems with spark plug in open chamber or per-chamber. The medium speed lean burn gas engines have been further developed by introducing micro pilot injection technique. The most promising one is direct injection of micro pilot which can be combined with diesel fuel injection to form a new concept of dual fuel combustion.

Medium speed engine development projects

- | | |
|---------|--|
| 1981-83 | <p><u>Utilisation of Boil-Off gas from LNG tankers.</u></p> <p>Design of engine concept, High-pressure injection of gaseous fuel. Design and manufacturing of high-pressure injection equipment for a laboratory medium speed diesel engine. Managing full-scale laboratory studies of the dual fuel gas engine concept using high-pressure injection of gas. Installation of a 16m³ LNG storage system with capability of 250 bar gas supply to the Machinery laboratory. /1/, /2/, /3/</p> |
| 1984-85 | <p><u>Development of the Otto Lean Burn gas engine concept K-type engine Bergen Diesel</u></p> <p>Development of the medium speed lean burn combustion system using pre-chamber spark ignition. Design and built a electronically controlled gas admission system. Rebuilt a 3-cylinder lab engine. Performed full-scale laboratory tests of the concept.</p> |
| 1986-91 | <p><u>The Wärtsilä Gas Diesel engine development.</u></p> <p>Development of a medium speed gas diesel engine using the high pressure injection of gas concept. The development work has been conducted continually during a period of about 5 years. The main activities during the development program has been:</p> <p style="margin-left: 40px;">Basic design of the concept, comprising design of combustion system, design of injection equipment, gas jet penetration and mixing studies. Installation of a 4 cylinder Vasa 22 medium speed diesel engine in the Machinery Laboratory. Design and manufacturing of a injection valve. Performing combustion study on one</p> |

cylinder. Installation of complete injection systems on all cylinders and control system. Full scale testing.

Installation of a 4 cylinder Vasa 32 medium speed diesel engine in the Machinery Laboratory. Full scale testing of a combined gas/fuel oil injection system.

Design of injection valve version 2 and 3 with corresponding full scale testing.

Development and testing of an electronic controlled injection system. Full-scale testing of the engine with complete control and safety system. /6/

- 1991-92 High pressure injection of LPG on Vasa 32.
Fundamental studies of injection and combustion of LPG jets. Numerical calculations and rig studies. Full scale testing of the concept on the Vasa 32 lab engine.
Installation of LPG storage system with 400 bar supply capability to the laboratory.
- 1994-96 Development of Lean Burn gas engine K-type. Ulstein Bergen
Further development of K-type as lean burn pre-chamber gas engine.
- 1996-99 Development of low pressure dual fuel engine, Wärtsilä.
Development of a new concept using dual nozzle injector with micro pilot capability
- 1997-98 Development of the B-type engine of lean burn micro pilot.
Installation of 6-cylinder B-type engine in the Machinery laboratory. Convert the engine to operate on 3-cylinders. Development of a high bmep lean burn gas engine using micro pilot ignition system.
- 2000- STID EU project
Development of a steam assisted diesel engine using the waste heat energy.

High speed gas engines

The lean burn heavy duty engine concept are used in CNG (compressed natural gas) and LPG powered buses and CNG powered trucks.

NTNU have been involved in projects related to high speed gas engine development and operation of CNG powered buses as indicated by the following list:

- 1989-91 Development and operation of a natural gas powered bus in Trondheim
- 1990 Conversion of a diesel engine to a lean burn natural gas engine
- 1990-92 Conversion of a diesel engine to a lean burn LPG engine

1991-92	Development of the Volvo THG 103 KF lean burn natural gas engine
1991-93	Development of the Scandia CNG engine
1991-92	Conversion of five diesel engines to bio-gas operation
1994-95	Development of LPG engine for Volvo Bus Corporation
1994	Further development of Volvo CNG engine for truck application
1995-96	Development of the Perkins Eagle 300 CNG engine
1995-97	Natural aspired LPG engine
1995-97	Perkins 900 series LPG engine
1996	Conversion of Volvo B10L low floor diesel bus to natural gas operation