2019 COURSE DIRECTORY

IC ENGINES & LUBRICANTS
A Word from the CEO
Jean-Luc Karnik

Our roots, our history

2019 is the 100th anniversary of the first oil training in France at the Pechelbronn field site, as well as the creation of the first oil laboratory, ancestors of the IFP and IFP School. A century later, IFP, now IFP Energies nouvelles, is recognized worldwide for its action and success in developing technologies and talents in the energy sector.

IFP Training, a subsidiary within the IFP group, was founded in 1975 to develop the skills of professionals in the Oil & Gas industry and now offers courses in fields as varied as exploration, production, refining, chemicals, the powertrain industry, energy transition, economics and management.

In addition to the “catalogue” training courses presented below, the core of the activity concerns tailor-made courses to customize the development of our clients’ teams, whether they are operators, engineers or managers.

In total, more than 15,000 professionals from 80 countries are trained each year through 1,400 training sessions.

Addressing our industry’s new challenges

Although the global demand for hydrocarbons increases, the high price volatility and geopolitical instability in some regions have a significant impact on the development of our industry, which can also be measured in the area of recruitment and training. In particular, there is a strong trend towards internalization and catalogue training courses are becoming commodities.

In addition, the new generations express high expectations often linked to the emergence of new training methods or new digital tools. They expect interactivity, practice and immediate impact of the training.

As a result, training is now seen as an investment in skills development, a guarantee of employability for employees and operational efficiency and enhanced safety for companies.

Our solutions

In this context, IFP Training develops a range of high value-added services and solutions and offers a skills management system, from evaluation to certification, guaranteeing a return on investment as well as a quality guarantee.

Close relations have been established with major players in the energy sector, particularly in Africa, Latin America, Europe, the Middle East and Russia. For example, we have partnered with TOTAL to offer training on real size industrial units to develop know-how and interpersonal skills.

I encourage you to read in the following pages about the resources and methods implemented, from our policy of pedagogical innovation and quality, our professionalization paths, our rich offer of training leading to certification, our competency assessment system to our global approach to accreditation.

Our teams and, in particular, our 100 permanent instructors and 600 industry experts are at your disposal to offer you high added value services and enable you to succeed in your projects.

Jean-Luc Karnik
Chief Executive Officer
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Introduction to Engines
Operating - Depollution - Technical Evolutions

Level: DISCOVERY

Purpose
This course provides a demystification of the operation of reciprocating conventional and future automotive engines as well as the related terminology.

Audience
Any person wishing technical information about automotive engines’ operation, SI or Diesel.

Learning Objectives
Upon completion of the course, participants will be able to:
▸ identify the main engine components and situate them in the engine,
▸ describe the operating mode of these components,
▸ understand spark ignition and Diesel combustion and describe their differences,
▸ have a view of the expected technological evolutions required by the future regulations.

Ways & Means
▸ Real engine dismantling.
▸ Real components study.
▸ Interactive talks.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ENGINES OPERATING & BASIC PARAMETERS 0.75 d
Piston engines operating and classification: 4-stroke and 2-stroke cycles, gasoline/Diesel, indirect/direct injection, naturally aspirated (NA)/supercharged (SC), architectures.
Geometric characteristics: conrod-crank system, bore, stroke, cubic inch displacement, compression volumetric ratio, timing diagram.
Operating parameters: load, use curve, torque, power, fuel/air ratio, volumetric efficiency, efficiencies, specific fuel consumption (BSFC).

ATMOSPHERE POLLUTION & REGULATIONS 0.25 d
Atmospherical phenomena: locally (smog) or globally (greenhouse effect).
Regulations for passengers cars.

DESCRIPTION & FUNCTIONS OF ENGINE COMPONENTS 1 d
Role of the engine in powertrain.
Main components technologies: piston, conrod, crankshaft, flywheel; cylinder block, cylinder head; camshaft drive, valve control, variable timing and their situation in the engine.
Injection systems: gasoline and Diesel. Ignition system.
Naturally aspirated (NA) engine intake circuits, turbocharging, exhaust gas recirculation (EGR), cooling, lubrication, crankcase ventilation.
Engine monitoring: torque structure, logic controller, sensors and actuators.
Components displays…

ENGINE OPERATION & BASE PARAMETERS 1.5 d
Reactants and combustion products, combustion equation, flammability limits, auto-ignition delay, combustion speed. Combustion in:
▸ Indirect injection spark ignition engines (stoichiometric homogeneous mixture).
▸ Direct injection spark ignition engines, in a homogeneous or stratified (heterogeneous) mixture.
▸ Direct injection Diesel engines (heterogeneous mixture).
Pollutants formation. Exhaust gas recirculation (EGR).
How to transform chemical energy in mechanical energy, thermodynamical work, 4stroke and 2 stroke cycles.
Evolution of SI engines and Diesel engines, downspeeding, downsizing…

FUELS FOR ENGINES 0.25 d
Hydrocarbons properties and structures: composition, H/C ratio, self-ignition, net calorific value (NCV).
Oils characteristics (octane rating, volatility) and Diesel fuels (cetane rating, cold engine operability, sulfur content, lubricating capacity). Biofuels.

EXHAUST GAS AFTER-TREATMENT 0.25 d
Automotive exhaust catalysis: oxidation catalysis and tri-functional catalysis.
Efficiency, initiation temperature, ageing.
Nitrogen oxide processing (NOx traps, selective reduction catalysts SCR).
Diesel particle filtration and filter regeneration with fuel additive or catalytic filter.
On Board Diagnostics (OBD).

AIR POLLUTION & REGULATIONS ORIGINS 0.25 d
Atmospheric phenomena at stake: local (smog) or global ones (greenhouse effect).
Regulations implemented to cars.

Reference: MOT/INTMOT-E  Only available as an In-House course.

Contact: mi.contact@ifptraining.com

This course is also available in French: MOT/INTMOT. Please contact us for more information.
Introduction to Hybrid & Electric Vehicle Propulsion

Level: DISCOVERY

Purpose
his course provides a deeper knowledge on the bases of hybrid and electric vehicles.

Audience
Engineers and technical staff wishing to increase their knowledge in the field of hybrid powertrain and to improve their understanding of the associated stakes.

Learning Objectives
Upon completion of the course, participants will be able to:

- know the main technical and economical stakes, the basic associated vocabulary, the proposed technologies and the expected fuel economy improvements,
- know the main components and technical ways to build an HEV.

Ways & Means
- Talk type training illustrated with a number of examples showing the economical and energy stakes.
- Real components study.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content
1 day

CONTEXT
Base definitions, orders of magnitude, why hybrid vehicles? Various hybrid types: hydraulic, pneumatic, inertia wheel… Impact of the type of vehicle use.
Homologation. ZEV running.
Stakes for car manufacturers.

ARCHITECTURE OF ELECTRIC HYBRID VEHICLES
General principles.
Serial hybrid. Well known examples: rail, bus…
Parallel hybrid. Conventional design.
Serial/parallel hybrid, power shunt, Toyota Prius 2, Prius 3, Chevrolet-Volt.

FUNCTIONALITIES OFFERED BY ELECTRIC HYBRID VEHICLES
Stop and start, regenerative braking, boost.
Operating point optimization, thermal engine load, ZEV driving, impact on ancillaries; other functionalities.
Fuel economy improvement.

HYBRIDS RANKING & ASSOCIATED FUNCTIONALITIES
Mild-hybrid. Installation, fuel economy.
Full-hybrid, plug-in hybrid. Stakes, necessary infrastructure.
Overview of existing hybrids.
Toyota Prius, Chevrolet-Volt: description, operating analysis.

ELECTRIC VEHICLES
Conventional vehicles with batteries, electric motor, motor wheel: various approach, CO₂ values Tank to Wheel or Well to Wheel.
Range-extender.
Fuel cell.

CONCLUSION
Impact of the context (political, regulation, industrial, economical…) on technical options.
Module 1: Fundamentals & Testing Methodology

Level: FOUNDATION

Purpose
This course provides an up-to-date knowledge on the fundamentals about energy conversion and measurements in combustion engines.

Audience
Engineers and technical staff of engine design, development or tuning departments, SI or Diesel. Applicants should be aware of engine components vocabulary.

Learning Objectives
Upon completion of the course, participants will be able to understand:
- the basic parameters on how engines operate and on hydrocarbons characteristics,
- the main differences between SI and Diesel engines,
- the measurements conducted at the engine dyno and roller bench.

It is recommended to fully master the contents of this module to attend the Module 2 “Spark Ignition Engines”, Modules 3 “Diesel Engines”. It is also necessary to master the contents of these modules to attend Module 4 “Introduction to the engine control module”.

Ways & Means
- Many real examples.
- Short calculations on real case data.

Prerequisites
Attendants should understand the main engine components and their functions.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

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<td>Primary and secondary pollutants.</td>
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<td>Air quality: space (local or global) and time scales. Consequences and impacts.</td>
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<td>Phenomena: ozone layer, greenhouse effect, acid rains, photochemical smog…</td>
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<td>Air quality standards, regulations applied to the car emissions and approval cycles.</td>
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<td>Operating parameters: Performance: torques (instantaneous, average), power, notion of load, use curve, cycle engine work, mean indicated pressure (IMEP), mean effective pressure (BMEP), friction mean pressure (FMEP), mean piston speed, thermal load and specific power.</td>
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<tr>
<td>Combustion/emissions: air/fuel ratio, stoichiometry, stoichiometric quantity, equivalence ratio, excess air coefficient, exhaust gas specific emissions.</td>
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<td>Air loading: volumetric efficiency, volumetric performance.</td>
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<td>Exercises.</td>
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<td>Pollutants formation, flammability limit, auto-ignition delay.</td>
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<td>Comparison of SI and Diesel engines:</td>
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<td>Combustion process: load control, preparing the air-fuel mixture, initiation, expansion, pollutants formation, exhaust gas recirculation (EGR), vibrations and noise origins.</td>
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<td>Full load performance limits: knocking, mechanics, thermo-mechanics, exhaust temperatures.</td>
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<td>In-use efficiency: downsizing, downspeeding.</td>
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<td>Exhaust gas after-treatment.</td>
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<td>Case of the gasoline direct injection (GDI).</td>
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<tr>
<td>Hydrocarbons structure and properties: alkanes, alkenes, aromatics, napthenes, H/C ratio, crude structures, main characteristics expected to meet SI and Diesel engines’ needs (volatility, octane and cetane ratings, cold engine operability, sulfur content).</td>
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<td>Interpreting the results.</td>
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<td>Measurements of exhaust emissions and evaporation losses.</td>
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<td>Evolution of analysis materials: trends and developments.</td>
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Reference: MOT/MOT1-E
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/MOT1. Please contact us for more information.
Module 2: Spark Ignition Engines
SI Engines

### Level: FOUNDATION

#### Purpose

This course provides a deeper knowledge on spark ignition SI engines.

#### Audience

Engineers and technical staff of engine design, development or tuning departments for Spark Ignition engines. For improved comprehension, applicants are advised to initially follow the Module 1.

#### Learning Objectives

Upon completion of the course, participants will be able to:

- understand the fundamentals behind combustion systems’ design and construction,
- understand how the gasoline characteristics affect the engine behavior,
- select depollution strategies: raw emissions improvement and/or after-treatment,
- build a quick diagnostic in case of operation failure.

#### Ways & Means

All trainers are industry experts, delivering real life examples.

#### Prerequisites

Module 1 "MOT/MOT1-E" training.

#### Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

### Course Content

#### COMBUSTION SYSTEMS CHARACTERISTICS 1 d

Objectives and design restrictions linked to the combustion chamber (shape, valves arrangement).

Combustion characteristics: combustion physics, volumetric efficiency (valve lift curve, IVO, EVO, IVC, EVC, crossing), combustion and cycle efficiencies, fuel/air ratio distribution, abnormal combustions (knocking, pre-ignition).

Combustion modes: stoichiometric combustion (basic system, downsizing), lean mixture combustion (indirect or direct injection, homogeneous or stratified), direct injection and supercharging. Validity of these combustion modes facing the current and future restrictions (emissions, consumption…).

Design and adjustment parameters: combustion system optimization in stoichiometric or lean mixture mode. Raw emissions reduction: pollutants formation mechanisms. Performance/depollution tradeoff at the engine level (preparing the mixture, EGR, dead volumes, variable timing…).

#### CHARACTERIZATION - BREATHING & SUPERCHARGING 0.5 d

Breathing: volumetric efficiency, timing, acoustic inlet (Kadenacy effect, ¼ wave,…), and exhaust (3Y manifolds, separate exhaust lines…) optimization.

Performances: potential of the different technologies, parameters affecting the performances.

Link between breathing and performances.

Supercharging: supercharging types, turbocharger operating and technology, mapping (characteristic fields), adaptation to engine, trade-off to carry out.

#### SPARK IGNITION ENGINE FUELS CHARACTERISTICS 0.5 d

Gasoline main characteristics and specifications: density, octane rating, volatility, chemical composition, sulfur, and impact on the engine behavior.

Impact of the fuel composition on regulated and non regulated pollutant emissions.


Gaseous fuels: natural gas vehicles (GNV) and liquefied natural gas (GPL).

#### ENGINE MANAGEMENT SYSTEM 0.5 d

Engine control system: role, definitions, history.

Acquiring the operating point: different sensors (speed, glow, pressure, temperature, positioning…).

Ignition: components (coils, plugs), anti-knock.

Air management: motorized throttle valve, variable timing, supercharging.

Depollution: fuel-air ratio control (oxygen sensor), evaporative emission system (canister), exhaust gas recirculation (EGR), exhaust air injection (EAI).

Strategy: torque structure and diagnostic.

#### SPARK IGNITION ENGINE AFTER-TREATMENT 0.5 d

Situation, history and general issues, regulation restrictions, operating of a catalyst.

3-way catalyst: stoichiometric conditions, fuel-air ratio control, cold start (hydrocarbons, exhaust thermal management), high power loop opening.

Lean mixture NOx treatment (homogeneous/stratified); NOx traps operating principles, exhaust heat exchanger.

Operating limits of gasoline catalysts ageing. Gasoline on Board Diagnostics (OBD).

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Reference: MOT/MOT2-E  Only available as an In-House course.

This course is also available in French: MOT/MOT2. Please contact us for more information.

Contact: ml.contact@ifptraining.com

www.ifptraining.com
Module 2S: Spark Ignition Engines Advanced Study & Simulations
SI Engines

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on spark ignition engines and practice with modelization and simulation.

Audience
Engineers and technical staff of engine design, development or tuning departments. Spark Ignition engines and aiming to develop their knowledge of the operating parameters and increase their knowledge of key technologies on the Euro 6 horizon. For a better understanding applicants are advised to preliminary follow the Module 1.

Learning Objectives
Upon completion of the course, participants will be able to:
► know the fundamentals about combustion systems design and construction,
► know how the gasoline characteristics affect the engine behavior,
► understand the structure and the basics on the engine control operation,
► select a timing system,
► build a quick diagnostic in case of operating failure,
► identify and know the key technologies of spark ignition engines that will be needed for Euro 6.
► explain the evolution of the main parameters (pollutants, lead, CA50, CSE, SMEs, volumetric efficiency, energy release, the different yields…); a change of regime in full load, a load variation at constant speed, using a variable valve timing system,
► specify a type of test campaign for the basic settings of a spark ignition engine.

Ways & Means
► All trainers are industry experts, delivering real life examples.
► Downsizing architecture case study.
► Use of numerical simulator: active learning.
► The participant can directly visualize the influence of each engine parameter.

Prerequisites
Module 1 “MOT/MOT1-E” training.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

COMBUSTION SYSTEMS CHARACTERISTICS  1 d
Objectives and design restrictions linked to the combustion chamber (shape, valves arrangement).
Combustion characteristics: combustion physics, volumetric efficiency (valve lift curve, IVO, EVO, IVC, EVC, crossing), combustion and cycle efficiencies, fuel/air ratio distribution, abnormal combustions (knocking, pre-ignition).
Combustion modes: stoichiometric combustion (basic system, downsizing), lean mixture combustion (indirect or direct injection, homogeneous or stratified), direct injection and supercharging; validity of these combustion modes facing the current and future restrictions (emissions, consumption…).
Design and adjustment parameters: combustion system optimization in stoichiometric or lean mixture mode. Raw emissions reduction: pollutants formation mechanisms, performance/depollution tradeoff at the engine level (preparing the mixture, EGR, dead volumes, variable timing…).

CHARACTERIZATION - BREATHING & SUPERCHARGING  0.75 d
Breathing: acoustic inlet and exhaust (3Y manifolds, separate exhaust lines…) optimization.
Parameters affecting the performances.
Supercharging: supercharging types, turbocharger operating and technology, mapping (characteristic fields), adaptation to engine, trade-off to carry out.

SPARK IGNITION ENGINE FUELS CHARACTERISTICS  0.25 d
Gasoline main characteristics and specifications: density, octane rating, volatility, chemical composition, sulfur and impact on the engine behavior.
New fuels: evolution of specifications and oxygen compounds.
Gaseous fuels: natural gas vehicles and liquefied natural gas.

ENGINE MANAGEMENT SYSTEM  0.5 d
Engine control system: role, definitions, history.
Acquiring the operating point: different sensors (speed, glow, pressure, temperature, positioning…).
Ignition: components (coils, plugs), anti-knock.
Air management: motorized throttle valve, variable timing, supercharging.
Depollution: fuel-air ratio control, EGR, EAI.
Strategy: torque structure and diagnostic.

SPARK IGNITION ENGINE AFTER-TREATMENT  0.5 d
Situation, history and general issues, regulation restrictions, operating of a catalyst.
3-way catalyst: stoichiometric conditions, fuel-air ratio control, cold start (hydrocarbons, exhaust thermics management), high power loop opening.
Lean mixture NOx treatment (homogeneous/stratified): NOx traps operating principles, exhaust heat exchanger. Operating limits of gasoline catalysts ageing.

SIMULATOR: FULL LOAD CHARACTERIZATION  0.5 d
The proposed simulator is a virtual engine bench on which we will conduct virtual testing by varying the parameters to show their impact.
To find optimal advance.
Measurement of a power curve, maximum torque, specific fuel consumption, filling analysis. Impact of the air and cylinder wall temperature on engine performance.

SIMULATOR: ENGINE CHARACTERIZATION AT 2000 RPM  0.5 d
Spark advance and CA50 analysis, ESC, ISC, engine performance measurement.
Spark advance tracking and analyze. Study of the burning speed, initiation time, engine performance, exhaust temperature…

Reference: MOT/MOT2S-E  Only available as an In-House course.
Contact: mi.contact@ifptraining.com
This course is also available in French: MOT/MOT2S. Please contact us for more information.
Module 3: Diesel Engines

Level: FOUNDATION

Purpose
This course provides technical knowledge on Diesel engines for cars and industrial vehicles.

Audience
Engineers and technical staff of engine design, development or tuning departments, Diesel engines. For improved comprehension, applicants are advised to initially follow the Module 1.

Learning Objectives
Upon completion of the course, participants will be able to:
- know how direct injection Diesel engines work: ignition physics, design and adjustment parameters optimization,
- know high pressure injection systems operation and evolution,
- understand how Diesel fuel characteristics affect the engine behavior,
- select a depollution strategy and an after-treatment system,
- match a turbocharger with an engine.

Ways & Means
Lecturers are industry experts, delivering real life examples.

Prerequisites
Module 1 "MOT/MOT1-E" training.

More info
The Diesel Engineers course may replace module 3 for participants who wish to have a 5-day enhanced version.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

3 days

COMBUSTION SYSTEM OPTIMIZATION

1 d
Pollutants formation mechanisms
- Fuel jet gas and liquid parts behaviors.
- Combustion system optimization
- Streamline inlet: swirl roles and measurement; trade-off with cylinder head tightness.
- Drawing of the cavity (bowl) machined in the piston head.
- Injection system required qualities.
- Exhaust gas recirculation (EGR)
- How it reduces nitrogen oxide rate. Interest of EGR cooling.
- High and low pressure EGR.
- Start and cold start
- Combustion deterioration factors causing fumes and noise.
- Structure and control strategy of glow plugs used on car engines.

SUPERCHARGING

0.5 d
Turbocharger operating and technology.
- Turbocharger adaptation process on an engine: determining the flow and the density in the intake manifold, choosing the supercharger, calculating the flow and the turbine expansion ratio, choosing the turbine.
- Fixed or variable geometry turbocharger (FGT or VGT), supercharging by two sequential turbochargers.

COMPRESSION IGNITION ENGINE FUEL CHARACTERISTICS

0.5 d
Diesel fuel main characteristics and specifications (density, cetane rating, viscosity, lubricating capacity, volatility, sulfur…) and impact on the engine behavior, additive properties.
- Impact of the fuel composition on the regulated and non regulated pollutant emissions.
- Biofuels: vegetable oil esters.

INJECTION SYSTEM TECHNOLOGY & MONITORING

0.5 d
Common-rail injection system: system description; systems evolution.
- High pressure pump; high and low rail pressure control.
- Fuel injector operating; flow in the injector nozzle, hydraulic flow.
- Rail technology; flow balance.

EXHAUST GAS AFTER-TREATMENT

0.5 d
Regulations evolution, depollution strategies.
- Oxidation catalysis: efficiency, initiation temperature, sulfur effect, positioning in the exhaust line.
- Nitrogen oxides after-treatment: NOx traps, selective reduction catalyst (SCR).
- Diesel particles after-treatment: Diesel particle filter (DPF); DPF regeneration with additives in the fuel or by filter catalytic coating; associated engine monitoring strategy.
Module 3S: Diesel Engines

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<td>Combustion deterioration factors causing fumes and noise.</td>
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<td><strong>SUPERCHARGING</strong></td>
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<td>Turbocharger adaptation process on an engine: determining the flow and the</td>
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<td>density in the intake manifold, choosing the supercharger, calculating the</td>
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<td>flow and the turbine expansion ratio, choosing the turbine.</td>
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<td>Fixed or variable geometry turbocharger (FGT or VGT), supercharging by two</td>
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<td>High pressure pump; high and low rail pressure control.</td>
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<td>Fuel injector operating: flow in the injector nozzle, hydraulic flow.</td>
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<tr>
<td>positioning in the exhaust line.</td>
<td></td>
</tr>
<tr>
<td>Nitrogen oxides after-treatment: NOx traps, selective reduction catalyst (SCR).</td>
<td></td>
</tr>
<tr>
<td>Diesel particles after-treatment: Diesel particle filter (DPF); DPF</td>
<td></td>
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<tr>
<td>regeneration with additives in the fuel or by filter catalytic coating;</td>
<td></td>
</tr>
<tr>
<td>associated engine monitoring strategy.</td>
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<tr>
<td><strong>SIMULATOR: ENGINE CHARACTERIZATION</strong></td>
<td>1 day</td>
</tr>
<tr>
<td>The proposed simulator is a virtual engine bench on which we will conduct</td>
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<tr>
<td>virtual testing by varying the parameters to show their impact:</td>
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<tr>
<td>Change of injection advance.</td>
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<tr>
<td>Change of rail pressure.</td>
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<tr>
<td>Change of EGR rate.</td>
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<tr>
<td>Change of boost pressure.</td>
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<tr>
<td>Change of injection quantity.</td>
<td></td>
</tr>
<tr>
<td>Study of the evolution of the engine main parameters (pollutants, CA50, CSE,</td>
<td></td>
</tr>
<tr>
<td>SMEs, volumetric efficiency, energy release, specify type of test campaign</td>
<td></td>
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<tr>
<td>for the basic settings of Diesel engine with DOE.</td>
<td></td>
</tr>
<tr>
<td>Curves analysis from an engine bench.</td>
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</tbody>
</table>

**Level:** FOUNDATION

**Purpose**

This course provides technical knowledge on Diesel engines for cars and industrial vehicles and the knowledge of the operating parameters.

**Audience**

Engineers and technical staff of engine design, development or tuning departments, Diesel engines. For improved comprehension, applicants are advised to initially follow the Module 1.

**Learning Objectives**

Upon completion of the course, participants will be able to:

- know how direct injection Diesel engines work: ignition physics, design and adjustment parameters optimization,
- master high pressure injection systems operation and evolution,
- understand how Diesel fuel characteristics affect the engine behavior,
- select a depollution strategy and an after-treatment system,
- match a turbocharger with an engine,
- explain the evolution of the main parameters (pollutants, CA50, CSE, SMEs, volumetric efficiency, energy release, the different yields…); a change of injection advance, a change of rail pressure, a change of EGR rate, a change of boost pressure, a change of injection quantity,
- specify a type of test campaign for the basic settings of Diesel engine with DOE.

**Ways & Means**

- To practice the knowledge on simulator using combustion models developed with GT Power: to understand the influence of various parameters settings on a supercharged EGR Diesel engine; to know how to conduct a test and analyze the data.
- Lectures are industry experts, delivering real life examples.
- Use of numerical simulator: active learning.
- The participant can directly visualize the influence of each engine parameter.

**Prerequisites**

Module 1 “MOT/MOT1-E” training.

**More info**

The Diesel Engineers course may replace module 3 for participants who wish to have a 5-day enhanced version.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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Reference: MOT/MOT3S-E

This course is also available in Arabic: MOT/MOT3S. Please contact us for more information.
Diesel Engineers

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on Diesel operation, combustion, injection systems, after-treatment fuels and lubrication (car, heavy duty trucks, off-road).

Audience
Engineers and technical staff of engine design, development or tuning departments, looking for a better understanding of Diesel road engines as well as industrial engines. For improved comprehension, applicants are advised to initially follow the Module 1.

Learning Objectives
Upon completion of the course, participants will be able to:
- understand Diesel engine operation: combustion process, pollutants origin and reduction,
- understand the engine-turbocharger adaptation criteria,
- size the turbocharger,
- know the associated products and their circuits: fuels and lubricants,
- select the right after-treatment system.

Ways & Means
- One of our best-sellers.
- More heavy-duty vehicles oriented, comparing personal vehicle, trucks, off-road on real basis.

Prerequisites
Module 1 "MOT/MOT-1-E" training.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

5 days

DIESEL ENGINES: COMBUSTION & OPERATING 1 d
Diesel combustion mechanisms: pollutants formation (particles, HC, CO, NOx), fuel jet required characteristics, air mixture, streamline in the combustion chamber (swirl and squish), combustion system optimization with regards to the performances/depollution trade-off. Interest of multiple injections (pilot injection, split injection, post-injection) as for noise and depollution. Combustion modes with improved air/fuel mixture: HPC (highly premixed combustion), HCCI (homogeneous charge compression ignition).

Exhaust gas recirculation (EGR): how it reduces nitrogen oxide rate, trade-off with low and high load particles emissions, EGR cooling, high and low pressure EGR. Start and cold start: factors of smoke and noise when cold; start assistance with warp up at intake, glow and post-glow plug.

COMBUSTION NOISE 0.25 d
Noise origin, measurements, cracking noise, burst noise. Solutions to reduce noise.

TURBOCHARGING 0.5 d
Inlet and outlet limits of turbocharging on Diesel engine: temperature before turbine, cylinder pressure, thermo-mechanical stresses in the cylinder head. Technologies of the different parts: compressor, turbine, main bearings. Adaptation of the turbocharger to a given engine: choosing the turbocharger, compressor map limits (pumping, overspeed, sonic cutoff), choosing the turbine, free-floating, wastegate or variable geometry control, twin-scroll turbine, dual turbocharging.

DIESEL ENGINE FUELS 0.5 d
Diesel fuel main characteristics and specifications (density, cetane rating, viscosity, lubricating capacity, volatility, sulfur…), and impact on the engine behavior, additives properties. Impact of the fuel composition on the regulated and non regulated pollutant emissions. Specifications: Diesel fuel compared with domestic fuel and with Jet A1, new Diesel fuels, methyl ester of vegetable oils (EMV).

INJECTION SYSTEMS TECHNOLOGIES 0.75 d
Description and operating of injection systems on cars and industrial heavy truck engines: low pressure circuits, pumps, ducts, injectors and nozzles. Managing the fuel injection laws with Common-rail systems, solenoid injector or piezo, injector pump, unit pumps, hydraulic assisted pumps. Design restrictions and precautions. Filtration. Evolutions.

ENGINE MANAGEMENT SYSTEM 0.5 d

DIESEL ENGINES LUBRICATION 0.5 d

EXHAUST GAS AFTER-TREATMENT 1 d
Situation, history and general issues, regulations and approval cycles. Mechanisms of Diesel oxidation catalysis specific reactions: catalyst structure and operating principle (noble metals, performances criteria, functional definitions, efficiency, field, initiation, conversion rate, sulfur and particles oxidation). Nitrogen oxides conversion: decomposition, selective reduction catalyst (SCR) hydrocarbons and ammonia, Diesel sequential. Specific treatments: NOx traps, liquid/solid urea DeNox, hydrocarbons SCR reduction. Particles treatment: particles structure, Diesel particle filters - DPF- (silicium carbide, ceramics, metallic), DPF regeneration (with additives or catalysis), consequences (consumption, ΔP, cost…). Evolution towards 4-way catalysis (DPNR, others…). Limiting Diesel catalyst ageing, Diesel On Board Diagnostics (OBD).

Reference: MOT/MDIES-E Only available as an In-House course.

This course is also available in French: MOT/MDIES. Please contact us for more information.

Contact: ml.contact@ifptraining.com

www.ifptraining.com
Technical Evolutions of Automotive Engines

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on technical evolutions of the current automotive engines, both SI and Diesel ones and provides an overview of the current drivers of engine design: emissions and fuel consumption.

Audience
Engineers and technical staff already aware of engine fundamentals and looking for an update of engines’ technical evolutions.

Learning Objectives
Upon completion of the course, participants will be able to:
- recognize and understand direct injection SI engines operation,
- know the advantages of downsizing in gasoline spark ignition engines,
- recognize and understand the Diesel issues and evolutions,
- know new ignition modes (CAI and HCCI),
- know timing adaptations and new ignition modes,
- know supercharging technology evolutions.

Ways & Means
- A complete overview presented by experienced engineers or industry project leaders.
- Focus on engine design drivers. Ranking of design constraints.

Prerequisites
Our MOT/MOT1-E training may be useful.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

GASOLINE COMBUSTION CONCEPTS & MODES, DIRECT INJECTION & DOWNSIZING 1 d
Gasoline direct injection (GDI):
- IDE advantages and drawbacks, strategies of use (R=1, stratified…).
- Two main groups of combustion chambers.
- System characteristics: injectors, HP pump, regulator, rail, electronic power unit.
- Examples of achievements.
Downsizing:
- Situation, stakes, consumption increase origin, difficulties to manage.
- Supercharging system specifications, different types of supercharging.
- Interest of coupling GDI with supercharging.
- Knocking management.
- Advantage of variable timing.
CAI (Controlled Auto Ignition): principle, interest and limits.

DIESEL COMBUSTION SYSTEM 1 d
Common rail Diesel direct injection:
- Evolutions leading to direct injection and common rail injection system globalization.
- Parameters driving the Diesel engine maximum performances.
- Interactions between different technologies in Diesel engines and the performances making it possible to reach them.
- Exhaust gas after-treatment: Diesel exhaust gas after-treatment principles.
HCCI (Homogeneous charge compression ignition): operating and conditions, interest, limits in high load and during transients.

VARIABLE TIMING SYSTEM 0.5 d
Timing role and restrictions, interest of variable timing.
Camshaft phase shifter, dual cam systems (Honda VTEC, Porsche VarioCam, Mahle), continuous variation systems (Valvetronic BMW, Toyota Valvematic system, Nissan VVEL, Multiair Fiat). Camless system.
Application to Miller/Atkinson systems.

SUPERCHARGING 0.5 d
Turbocharger role, restrictions and dimensioning.
Turbocharger technology evolution in relation to the engine evolutions: restrictions related to pressure increase and ignition temperatures (downsizing), interest of the dual inlet turbine (Twin Scroll).
Response lag optimization: main bearings or roller bearings, compressor pre-launch by coupling, volumetric compressors.
- Evolutions: variable nozzle geometry (VNT), coupled turbochargers (serial or parallel), “e-Boosting”.

Reference: MOT/ETMA-E Only available as an In-House course.
Contact: ml.contact@ifptraining.com
This course is also available in French: MOT/ETMA. Please contact us for more information.
Hybrid & Electric Powertrains

Course Content

**ELECTRIC HYBRID POWERTRAINS**

Factors leading to such technologies emergence (interest and stakes).
Two categories of hybrid architectures: serial, parallel.
Parallel architectures.
Single shaft, reversible starter generator in the accessories drive (STT + Adex), full hybrid.
Dual shafts, hybrid wheels, power shunt (DR), n mode power shunt (DRnM).
Consumption improvement functions: Stop and Start, regenerative braking, energy optimization, consumption measurement method, performances comparison, pollution.
New units: combustion engine, electrical machine, inverter, converter, booster, battery.
Overview, technico-economic balance and conclusions.
Electric vehicles.

**ON-BOARD ENERGY STORAGE SYSTEMS**

Electrochemical battery: operating principle, characteristics and performances of the different technologies (lead-acid, cadmium-nickel, hydrogen-nickel, lithium-ion, lithium-polymer).
Ultra capacitor: principles, performances.
How it is inserted into the vehicle.

**POWER ELECTRONICS**

Power components: Mosfet, IGBT…
Power electronics structures: DC-DC, DC-AC converters…
Power characteristics, installation restrictions, thermal and vibratory aspects. Electro-magnetic compatibility.

**ELECTRIC MOTOR**

Electric motor different technologies: operating principles, characteristics, performances, evolution.
Installation restrictions: compactness, cooling.
Examples of applications to vehicles.

**SYSTEM OPERATION - MANAGEMENT PRINCIPLES**

How to manage electric motors and converters? Which physical principles for which result?
Main functions, secondary functions.

**HYBRID PROPELLERS & ENERGY MANAGEMENT**

Energy flux and energy supervision.
Meaning for serial, parallel and serial/parallel hybrids.
Objectives and restrictions: consumption, pollution, state of charge management, regenerative braking, stop/start functions, thermal engine boost, drive approval.
Techniques: empirical controls, application to a series vehicle, improvements offered to empirical controllers, optimum controllers.
Synthesis and controllers validation: use of system models, off-line optimization methods and adaptation and optimization online.
Application examples to vehicles.

**THERMAL MANAGEMENT**

Thermal management of electrical main components. Installation restrictions.

**VEHICLE INSTALLATION**

Manufacturing process of a complete system: storage system and drive chain dimensioning.
Installation restrictions, passenger compartment cooling.

Ways & Means

- One of our best-sellers.
- Interactive talks, based on real examples and components.
- It covers all main technical fields of hybrid powertrains.
- Orders of magnitude are clearly given.
- Our training MOT/SIMHY-E can be added to MOT/GMPH-E as an optional 5th day.

Prerequisites

No prerequisites for this course.

More info

This program can be completed by a study on modeling Hybrid Power Trains and Hybrid architecture with simulator and Toyota Prius testing & analysis. Select next page “Electrical Powertrain & hybrid modeling, Simulations, & Hybrid Measurements” GMPHS.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.
Hybrid & Electric Powertrains - Modelings, Simulations, Measurements & Analysis

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on modeling and simulation of hybrid vehicles and powertrain. Reinforce knowledge by experimenting measurements and analyses on a Toyota Prius.

Audience
Engineers and technical staff wishing to increase their knowledge of electric hybrid automotive powertrains.

Learning Objectives
Upon completion of the course, participants will be able to:
- understand the general situation of current hybridization, the different hybridization forms of road vehicles,
- know the different types of batteries and electric motors adapted to hybrid vehicles,
- know the issues of on-board hydrogen,
- simulate a hybrid drive chain operation,
- identify the main components of the drive chain,
- describe how they work and to describe the operating modes of a hybrid vehicle.

Ways & Means
- One of our best-sellers. Mainly interactive, supported by examples and real components, this training course covers all main technical fields of hybrid powertrains.
- Orders of magnitude are clearly given.
- Design of hybrid vehicle model and simulator on Matlab-Simulink. This Matlab-Simulink simulator is operational and functional. It can be used as a basis for further studies that students can achieve in their professional job.
- Measurements and analyses of a Toyota Prius 2. Participants can compare measurements on the model and numerical simulation.
- Architecture study with active learning: participants simulate architectural choices’ impact on a AMESIM simulator.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ELECTRIC HYBRID POWERTRAINS 1 d

ON-BOARD ENERGY STORAGE SYSTEMS 0.5 d
Electrochemical battery: operating principle, characteristics and performances of the different technologies (lead-acid, cadmium-nickel, hydrogen-nickel, lithium-ion, lithium-polymer). Ultra capacitor: principles, performances.

POWER ELECTRONICS 0.5 d

ELECTRIC MOTOR 0.5 d
Electric motor different technologies: operating principles, characteristics, performances, evolution. Installation restrictions: compactness, cooling.

SYSTEM OPERATION – MANAGEMENT PRINCIPLES 0.5 d
How to manage electric motors and converters? Which physical principles for which result? Main functions, secondary functions.

HYBRID PROPELLERS & ENERGY MANAGEMENT 0.5 d

THERMAL MANAGEMENT 0.5 d
Thermal management of electrical main components.

VEHICLE INSTALLATION 0.25 d
Manufacturing process of a complete system: storage system and drive chain dimensioning. Installation restrictions, passenger compartment cooling.

IDENTIFICATION OF POWERTRAIN COMPONENTS 0.25 d
Directly on the vehicle mock-up. Description of the vehicle. Thermal engine. Electromotors MG1 et MG2. ECU. AC/DC and DC/DC converters. Understanding of the vehicle architecture and drive train.

OPERATING MODES DEMONSTRATION 0.25 d

VIEW OF ENERGY FLOWS 0.25 d
Measuring the main electric characteristics in the main branches. View of energy flows. Simulation of various use situation.

COMPUTERIZED SIMULATION 0.25 d

Reference: MOT/GMPHS-E  Only available as an In-House course. Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/GMPHS. Please contact us for more information.
Electric Drives for Automotive Propulsion Design, Modeling & Simulation

Course Content

**Level:** ADVANCED

**Purpose**

This course provides a deeper knowledge on how to design, build a model and simulate electrical drives, integrate the automotive needs and constraints.

**Audience**

Design or test engineers or technicians, currently working at manufacturers or OEM in automotive trucks or off-road fields and wishing to design, develop, model, simulate, specify or use electrical drives in electric and hybrid projects involving technical and economic constraints.

**Learning Objectives**

Upon completion of the course, participants will be able to:

- know the fundamentals of electric drives,
- know cooling technologies for electrical machine and power electronics,
- understand design, build a model and simulate electrical drives including gearbox and dynamic aspects,
- understand, design, build a model and simulate electrical machines, power electronics and cooling systems,
- integrate the automotive technical, industrial and economic constraints in system design and make architectural choices.

**Ways & Means**

- Interactive talks with experts from automotive industry.
- Some components are dismantled and studied.
- The design electrical equations are suitable to specify a large number of automotive electrical drives.
- Modeling and simulation of power electronics allow students to understand the design and the operation of this kind of devices.
- Modeling and simulation of electrical drives allow students to understand the design and the operation.

**Prerequisites**

“Hybrid and electric powertrains” training course is recommended for people outside electric sector or beginner in this area or a basic knowledge of electrical engineering and electromagnetic phenomena is recommended.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

**References:**

**TOGL**

1. Reference: MOT/MOTLECS-E

2. Only available as an In-House course.

**Contact:**

mt.contact@ifptraining.com

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**AUTOMOTIVE ELECTRICAL DRIVES**

Fundamental of electrotechnics: electrical measurements, electrical components: magnets, conductors, magnetic materials, magnetic circuits, production of magnetic fields, magnetic forces, electromagnetic induction, impedances (inductors, capacitors, electrical circuits), vector calculations (voltage and sinusoidal voltages, vector diagram, power calculation, currents, active and reactive power), electrical machines losses, performances and dimensions, single and three phase, real and ideal transformers.

**DC machines:** fundamentals, equivalent electrical circuit, design rules, design and layout constraints, manufacturing processes, industrial and economic aspects, examples of vehicle applications.

**Synchronous machines:** fundamentals, equivalent electrical circuit, design rules, design and layout constraints, manufacturing processes, industrial and economic aspects, examples of application of vehicle.

**Induction machines:** fundamentals, equivalent electrical circuit, design rules; design and layout constraints; manufacturing processes, industrial and economic aspects; examples of application of vehicle.

**Cooling:** cooling technologies, design rules, electrical machines heat losses calculation.

**AUTOMOTIVE ELECTRICAL DRIVES POWER ELECTRONICS**

Power electronics for machines control: choppers, inverters, rectifiers; technology, design and operation; characteristics, layout constraints, thermal and vibration aspects; electromagnetic compatibility; manufacturing processes, industrial and economic aspects; examples of vehicle applications.

**Power components:** fundamentals, design and operations; conduction and switching losses; cooling technologies, design rules and operation.

**AUTOMOTIVE ELECTRICAL MACHINES CONTROL**

Reminders on electrical machines control with electric or hybrid vehicles. Torque and speed control issues.

**PWM construction and theory.** DC machines torque control.

**Vector control.** Park Equations. Flux and torque control of synchronous and induction machines.

**Sliding mode control of induction motors.**

**POWER ELECTRONICS DESIGN, MODELING & SIMULATION**

Chopper design, modeling and simulation with PSpice.

Bridge and three-phase inverter design, modeling and simulation with PSpice. Power electronics losses modeling.

**ELECTRIC MACHINES MODELING & SIMULATION**

Electric machines modeling and simulation with equivalent circuits.

**DC machine modeling and simulation.** Real machine datasheet analyzes. Model design and calibration with Matlab-Simulink. DC machine and chopper torque control modeling and simulation.

**Induction machine modeling and simulation.** Real machine datasheet analyzes. Model design and calibration with Matlab-Simulink.

**Induction machine and three-phase inverter chopper torque control by sliding speed modeling and simulation.**

**Synchronous machine modeling and simulation.** Real machine datasheet analyzes. Model design and calibration with Matlab-Simulink.

**Synchronous machine and three phase inverter torque control by oriented vector control (implementation of equations Park) modeling and simulation.**

**Reference:** MOT/MOTLECS-E

**This course is also available in French: MOT/MOTLECS. Please contact us for more information.**

www.ifptraining.com
Current & Future Fuels: Development & Evolution of Biofuels

**Level:** ADVANCED

**Purpose**
This course provides a thorough understanding of the evolution of motor fuels, which is closely linked to the reduction of the vehicle emissions. The first 2 days deal with the current fuels, while alternative fuels are treated during days 3 and 4.

**Audience**
Engineers, and technicians from all industries concerned by motor fuel evolution: car makers, refining, fuels traders, agro-fuels manufacturers...

**Learning Objectives**
Upon completion of the course, participants will be able to:
- list the key properties for automotive fuels (now and in the future),
- identify the main trends of fuel evolution due to: new regulations and/or new motor technologies,
- describe how catalytic converters allow a significant reduction of the contaminants from the exhaust gases,
- describe the different ways to manufacture the main alternative fuels, and the impacts of those on the vehicle emissions.

**Ways & Means**
Use of pedagogical games. The first 2 days are dedicated to the current fuels and presented by a refining expert. The 2 following days, alternative fuels (current and next generations) are presented by experts of the different branches.

**Learning Assessment**
Multiple choice quiz at the end of the session.

**Prerequisites**
No prerequisites for the 4 day course. The participants who wish to follow only the second part of the session, should have followed the course “Petroleum Products - Properties & Manufacturing Schemes” or have a solid knowledge of current fuels.

**More info**
It is possible to follow only the last two days of the course, in particular for the participants who would have already followed the course “Petroleum Products - Properties & Manufacturing Schemes”.

**Expertise & Coordination**
Technical expert in the area of petroleum product manufacturing.

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**Course Content**

**GASOLINE**

- Market trends and shares of different gasoline grades.
- Principle of the spark-ignition engine.
- Required properties for automotive gasoline:
  - Combustion: nature and incidence of knocking, chemical composition/combustion quality relationship, definition and measure of the gasoline octave numbers.
  - Toxicity: aromatics and olefins content.
  - Corrosiveness and stability.
- Exhaust gas pollution: gas composition and impact on the environment.
- Relations between gasoline specifications and vehicle regulations (EURO 6 standard).

**DIESEL FUEL**

- Market trends.
- Principle of the compression-ignition engine.
- Required properties for Diesel fuel:
  - Cold flow properties: cloud point and Cold Filtering Plugging Point (CFPP).
  - Pollution by exhaust gases: particles, NOx;
  - Compositional constraints: reduction of polyaromatic components (PAH - PolyAromatic Hydrocarbons) - High impact on the diesel fuel manufacturing.
- Relations between diesel-fuel specifications and vehicle regulations (EURO 6 standard).
- Diesel fuel formulation and manufacturing (hydrodesulfurization unit - in line blending).

**ALTERNATIVE FUELS FOR GASOLINE & DIESEL ENGINES**

- Alternative fuels: background and challenges, production routes, well to wheel cycle.
- Alternative fuels for gasoline engines: ethanol and ETBE.
- New manufacturing paths to meet the new and more severe constraints on ecological balance. Flex-fuel engine.
- Role of the new alternative fuels in the reduction of the CO2 emissions of the vehicles.
- Alternative fuels for diesel engines: fatty acid esters and hydrotreated oils.
- Characteristics and impacts of the fatty acid esters on the engine performance.
- Potential issues linked to the presence of fatty acid esters: storage stability, oxidation stability, low temperature operability.
- Second generation alternative fuel for diesel engine BTL. Synthesis alternative fuels GTL and CTL.

**ALTERNATIVE FUELS FOR TURBINES - BIOMASS RESOURCE BALANCE - GASEOUS FUELS**

- Alternative fuels for turbines (aeronautics):
  - Main production routes certified (or soon certified) of Biojetfuels: hydrotreated vegetable oils, synthetic biojets, biological pathways. Impact on: logistics, the aircraft, and the performance of the turbine.
- Possible sources of biomass resource:
  - 1st generation, new sources: used oils, jatropha…
  - 2nd generation: lignocellulosic pathway
  - 3rd generation seaweed based.
- Gaseous fuels:
  - LPG, LNG and DME.
  - Hydrogen: principle, performance and constraints related to the use of the fuel cell.

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Reference: APD/AUTFUEL. Only available as an In-House course. Contact: rc.contact@ifptraining.com

This course is also available in French: APD/CARBAUT. Please contact us for more information.
New Fuels & their Impact on IC Engines & Turbine Operation

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on issues raised by the use of the new fuels planned for the near or further future: biofuels, gaseous fuels, synthetic fuels, alternative jet fuels.

Audience
Engineers and technical staff involved in motor fuel quality management in relation to engine technologies.

Learning Objectives
Upon completion of the course, participants will be able to:
- understand the economical and environmental context of biofuels developments,
- describe the processes to obtain such fuels as well as their economic and environmental impact,
- know the main characteristics of these fuels,
- understand their impact on IC engines and turbine operation,
- adapt engines and vehicles adaptations when using these fuels.

Ways & Means
Full up-to-date training by a worldwide fuel expert and industry experts.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

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<thead>
<tr>
<th>FUELS STRUCTURE &amp; MAIN PROPERTIES</th>
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<tr>
<th>SYNTHETIC FUELS: GTL, BTL, CTL</th>
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<tr>
<td>Processes to get such fuels. Economic and environmental impacts.</td>
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<th>BIOFUELS</th>
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<tr>
<th>OTHER ALTERNATIVE FUELS</th>
<th>0.25 d</th>
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<tbody>
<tr>
<td>Synthesis alternative fuels: GTL, BTL, Methanol (production processes). Economical and environmental impact.</td>
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<tr>
<th>GASEOUS FUELS: GPL-C, NGV (NATURAL GAS VEHICLE), DME, HYDROGEN</th>
<th>0.25 d</th>
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<tr>
<td>Origins and resources of these fuels.</td>
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<tr>
<th>IMPACT OF NEW FUELS ON IC ENGINES &amp; TURBINES OPERATION</th>
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Reference: MOT/BIOMOT-E Only available as an In-House course. Contact: ml.contact@ifptraining.com This course is also available in French: MOT/BIOMOT. Please contact us for more information.
Automotive Drive Train
Architecture - Gear adaptation - Lubrication

Level: FOUNDATION

Purpose
This course provides a better understanding of drivetrains to deal with engine/vehicle adaptation topics, the restrictions found on both engine/drivetrain units and the topics on the powertrain development.

Audience
Engineers and technical staff working in the field of IC engines and wishing to know the role of automotive transmissions and their impact on powertrain operation.

Learning Objectives
Upon completion of the course, participants will be able to:
- know the main types of transmission,
- understand powertrain matching,
- describe and manage interactions between engine and transmission,
- carry out an engine project with the perspective of developing a whole powertrain.

Ways & Means
- Interactive talks by industry experts.
- Acquired Knowledge game tests.
- Gear ratio selecting exercises.
- Automatic transmission laws selecting exercise.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

AUTOMOTIVE TRANSMISSIONS TYPES 0.25 d
Elements making up a power transmission chain: clutch, gearbox, longitudinal axle, powered axle, driveshaft.
Stepped gear or continuously variable transmissions, gearing with or without breaking torque, manual or electronically driven operation.

AXLES & DIFFERENTIALS 0.25 d
Differentials: description, operation principle, limits and technical solutions.
Axles: different types (conical, hypoidal, wheel and screw): respective advantages and drawbacks.
Lubrication: lubricants requirements depending on the types.

MECHANICAL GEARBOXES ARCHITECTURES 0.5 d
Mechanical gearbox, 2, 3, or 4-shaft architectures, volume and powertrain assembly restrictions.
Automated, consumption-optimized, or sport mechanical gearboxes.
Dual clutch gearbox, architecture and operating.

CLUTCH & TORQUE TRANSMISSION 0.25 d
Conventional mechanical clutch, double mass flywheel, automatic clutches.
Operating and dimensioning: structuring parameters, impact on engine.
Failures, wearing parameters.

AUTOMATIC TRANSMISSION ARCHITECTURE 0.5 d
Hydraulic automatic gearbox, architecture, volume and powertrain assembly restrictions, related controls.
Continuous variation transmission (CVT), architecture and operating. Non automotive applications, Infinitely variable transmission (IVT), hydrostatic transmission.

ELECTRONIC POWERTRAIN TUNING 0.25 d
Automated mechanical transmission, dual clutch transmission, hydraulic automatic gearbox: control laws and tuning general rules.
Electronic architectures, ECU, logic controller, development parameters.

MATCHING & INSTALLATION 0.5 d
Installation, volume and thermal restrictions. Impact on vehicles architectures.
Gearing command: manual, assisted, automated, mechanical, semi-mechanical or electronically controlled.
Vehicle adaptation principles, optimization criteria: performances, emissions, consumption, NVH (noise, vibrations and harshness).
Taking additional restrictions into account.
Exercises.

INDUSTRIAL VEHICLES TRANSMISSIONS 0.5 d
Mechanical transmissions: main differences with passenger cars (relay boxes, vehicle retarders…). Lubrication requirements. Manufacturers’ specificities.
Automated transmission: application specificities compared with passenger car.
Case of agricultural machines or works machines.

Reference: MOT/TRANSM-E
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/TRANSM. Please contact us for more information.
Engine Technical Evolution

Course Content

<table>
<thead>
<tr>
<th>Level: FOUNDATION</th>
</tr>
</thead>
</table>

**Purpose**

This course provides a deeper knowledge on the technical evolutions of passenger car combustion engines and the reasons for such evolutions. It may be very useful for automotive suppliers needing an up-to-date overview of the engine world for passenger cars as well as for commercial vehicles. It delivers the keys of the specifications they obtain from their customers.

**Audience**

Engineers and technical staff wishing an update of the technical evolution: new combustion processes, regulation reinforcement, fuel economy improvement. People working at OEM as well as automotive suppliers.

**Learning Objectives**

Upon completion of the course, participants will be able to:

- know current and future evolutions of SI and Diesel engines,
- understand the physics that have led to the adopted solutions,
- apply technical solutions in the context of engine design,
- competently exchange between manufacturers and suppliers.

**Ways & Means**

- One of our bestsellers.
- Short talks associated to a play approach of IC engines.
- Short technical videos.

**Prerequisites**

No prerequisites for this course.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

<table>
<thead>
<tr>
<th>Course Content</th>
<th>2 days</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTRODUCTION</strong></td>
<td>0.25 d</td>
</tr>
<tr>
<td>Efficiencies and conventional parameters of an engine, the most useful graphs.</td>
<td></td>
</tr>
</tbody>
</table>

| **DEPOLLUTION & FUEL CONSUMPTION RESTRICTIONS** | 0.25 d |

| **GASOLINE TECHNOLOGY EVOLUTION** | 0.5 d |
| Normal and abnormal combustion (knocking, pre-ignition, rumble). Engine air loading: how the different parameters affect the evolution of the volumetric efficiency depending on the speed, use of intake and exhaust pressure waves to improve the load. Variable timing – Interest and technical solutions: camshafts phase shifters, dual-cam systems, mechanical continuous variation, camless, Miller and Atkinson cycles. Gasoline direct injection (GDI): technology, advantages and drawbacks, fuel/air ratio 1 or stratified strategies. Downsizing, interest of combining GDE + supercharging + variable distribution. |

| **DIESEL TECHNOLOGY EVOLUTION** | 0.5 d |

| **EXHAUST GAS AFTER-TREATMENT** | 0.25 d |
| SI engines: 3-way catalysis, catalyst initiation issue. Diesel engines: oxidation catalyst, Diesel particles filter performances and regeneration, 5th injector advantages and drawbacks. NOx trap. SCR (Selective Catalytic Reduction). |

| **ENGINE MANAGEMENT** | 0.25 d |

Reference: MOT/EVOLMOT-E  Only available as an In-House course. Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/EVOLMOT. Please contact us for more information.
Engine Operating Physics

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on engine operating physics, under the mechanical aspects, air loading, fuel injection, ignition, exhaust gas after-treatment.

Audience
Engineers and technical staff from design department, testing department wishing to improve their knowledge on following items: engine operation, physics of engines, components design.

Learning Objectives
Upon completion of the course, participants will be able to:
- calculate real flow sections in the cylinder head, in EGR circuits or any other fluid circuit,
- understand and apply the calculation formulae used during dyno bench tests,
- analyze some test results on emissions and efficiency,
- analyze the component damage and failure causes,
- understand the language and the tools used to analyze vibrations.

Ways & Means
Many exercises simulating everyday situations in every chapter.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

WEEK 1
Engine thermodynamic operating (1.5 days)
- History.
- Compressor isentropic efficiency.

Engine architecture - Performance and efficiency parameters (2 days)
- Geometric parameters: bore, stroke, volumetric ratio, timing diagram.
- Effective mean pressure: MEP, MFP, MIP.
- Real cycle, differences with theoretical cycle.
- Global efficiency: analysis using the 4 efficiencies and setting parameter influence.
- Fuel/air ratio, volumetric efficiency: calculation of the main engine parameters at stabilized rpm.
- Adaptation to the vehicle: Williams line.

WEEK 2
Engine mechanics (1.5 days)
- Acyclism
  - Determine the movements of stresses due to gas pressure in the parts.
  - Stresses caused by gas pressure and inertia stresses, impact of the conrod spacing on acyclisms.
  - Acyclism consequences and solutions to limit their impact on the powertrain.
  - Balancing
  - Inertia stresses caused by the rotating weight and the alternative weight.
  - Calculation of rotating and alternating inertia forces.

- Timing: description of the different valve control types, lift law, valve timing.

Air loop (2 days)
- Link between loading and performances. Fluid mechanics.
- Air loading.
- Variable timing: presentation of the main technologies and their applications.
- Turbocharging: operating, technology, mapping, adaptation process.

WEEK 3
Combustion (2 days)
- Gasoline combustion: flame front propagation, influence of turbulence; influence of the burning rate (HLC) and of the combustion timing (CA 50) on the efficiency; exhaust gas composition depending on the equivalence ratio; calculation of specific emissions; abnormal combustions (knock, pre-ignition, rumble).
- Diesel combustion: self-inflammation delay, pre-mixture and diffusion flames, formation of pollutants (PM, NOx, HC, CO).
- Common-rail injection systems; swirl number, EGR.

Fuels (1 day)
- Fuels groups: fuel main required properties for engine operating (heat value, volatility), octave and cetane ratings, Diesel fuel resistance to cold, sulfur content…
- Manufacturing process of fuels in a refinery.
- Biofuels: fuels-ethanol mixtures, vegetable oils, fatty acid esters.

Exhaust gas after-treatment (0.5 days)

WEEK 4
Materials - Mechanical strength (1.5 days)
- Metallurgist basic tools: iron/carbon diagram, TTT, CCT. Characteristics of the alloy steels used in the automotive industry: cast irons, steels, alumina. Rough casting manufacturing processes. Surface treatment. Parts mechanical properties: Young's modulus, minimum yield, shear rating. Analysis of the engine major parts whose material and manufacturing process have to be chosen.

Part damage modes (1 day)
- Thermal, mechanical and tribologic damages. Goodmann diagram. Stribleck curve.

Vibro-acoustics/NVH (1 day)
- Waves and sound: magnitudes defining a wave, propagation mode (air, solids). NVH vocabulary: dB, dBA, harmonics, resonance…
- Signal creation and lock-on, analysis and interpretation (sonogram, tracking).

Reference: MOT/PHYM-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/PHYM. Please contact us for more information.
IC Engine Training for Engineers

Level: ADVANCED

Purpose
This course provides a high level, modern training in the engine field (gasoline and Diesel). Because of the duration, the training can be recognized by a ENSPM diploma of Internal Combustion Engines Specialized Master, awarded by IFP School, provided satisfying results are obtained at the tests and a good assessment is given on the work done in the framework of a professional thesis development.

Audience
This training is mainly dedicated to automotive companies who want to train a group of engineers. Engineers from automotive industry, not directly involved in IC engine field and wishing to become engine specialists.

Learning Objectives
Upon completion of the training, participants will have acquired the requested knowledge and skills to be engine engineer. Upon completion of the course, participants will be able to:
- know every field of IC thermal engine,
- act as an experienced engineer as well as a project leader.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

INTRODUCTION TO ENGINE STUDY & TESTS 3 d

THERMODYNAMICS APPLIED TO ENGINES 2 d
Going through real cycles, methods and practical.

HYDROCARBONS & CAR FUELS 3 d
Introduction to refining. Gasoline fuels, Diesel fuels and biofuels: characteristics and adaptation. Composition/exhaust emissions relations.

COMBUSTION - EXHAUST EMISSIONS & AFTER-TREATMENT 7 d

PERFORMANCES & MEASUREMENTS 3 d
Practical on dyno bench and on simulator: parametric physic measures, engine performances characterization, exhaust gas analysis, interpretation of results.

ENGINE ARCHITECTURE & TECHNOLOGIES 7 d

MATERIALS & PROCESSES 4 d

ENGINE THERMICS - LUBRICATION & LUBRICANTS 2 d
Cooling: thermal balance and engine needs, restrictions and design of the cooling circuit, Diesel specificities. Lubrication and lubricants: tribology, roles, characteristics and classifications, how it affects after-treatment, lubrication circuit, blow-by gas.

LOADING & COMPONENTS OF THE AIR CIRCUIT 6 d
Loading: pressure losses, acoustic applied to loading intake and exhaust lines, supercharging. Supercharging: turbocharger operating, technology, adaptation to engine. Other components: throttle valve, EGR, interface with the engine control.

DIESEL & GASOLINE INJECTION SYSTEMS - IGNITION 5 d

CONTROL & PTD (POWERTRAIN DEVELOPMENT) 9 d
PT control: automatisms, gasoline and Diesel torque structure, gasoline and Diesel depollution, EGR and OBD. PT supervision and inter-systems. Development: gasoline and Diesel PTD, automatic transmission. On simulator: study and calibration of a control law.

GEARBOX & TRANSMISSIONS 2 d
Manual, robotized and automatic gearboxes: principles and technologies, clutch and damped flywheel clutch, differential, transmission cams and seals.

ADAPTATION OF THE PWT TO THE VEHICLE 2.5 d
Vibro-acoustics: bases, PT characterization, lab methods, pressure pulsation noises and sound quality. PT installation in a vehicle.

HYBRID & ELECTRIC PWT 1 d

RELIABILITY 3 d
Introduction to damage modes. Rules of analysis. Failure examinations.

EVALUATIONS - CONCLUSIONS 0.5 d

Reference: MOT/INGMOT-E

Only available as an In-House course.

Contact: mt.contact@ifptraining.com

This course is also available in French: MOT/INGMOT. Please contact us for more information.

www.ifptraining.com
Level: FOUNDATION

Purpose
This course provides a deeper knowledge on mechanical operations and behavior and challenges of air induction, combustion, thermodynamics, performance improvements…

Audience
Engineers and technical staff involved in the design, development and testing of spark ignition engines and equipment. Well adapted to trainings abroad.

Learning Objectives
Upon completion of the course, participants will be able to:
- calculate effective sections of a cylinder head or EGR circuit,
- understand and apply the equations used on the engine test bench,
- analyze the causes of engine component damage or failure,
- understand the vocabulary and tools used in the vibration analysis field,
- calculate and select a turbocharger to match a performance curve (turbo matching).

Ways & Means
All the training below includes many practical exercises to illustrate the concepts presented.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

THERMODYNAMICS APPLIED TO ENGINES 1.5 d
Engine history: evolution till the 4-stroke engine.
Thermodynamics first and second principles: calculation of an exhaust temperature. Why compressing before combustion?
Engine efficiencies: calculation of the engine best possible efficiency.
Calculation of cylinder pressure at compression end. Internal energy, enthalpy, entropy. Ideal gas equation. Laplace equation.
Different thermodynamic cycles (Beau de Rochas, Diesel, Atkinson, Miller, Stirling).
Turbocharger isentropic efficiency.

PERFORMANCE & EFFICIENCY 2 d
MEP: analysis of energy per cycle by mean pressure: BMEP (Brake Mean Effective pressure), IMEP (Indicated Mean Effective Pressure), FMEP (Friction Mean Effective Pressure).
Global efficiency: analysis of the 4 main efficiencies of a reciprocating engine, fuel consumption (BSFC), impact of different settings (load, A/F ratio, ignition timing…) on the efficiencies. Differences between the ideal cycle (Beau de Rochas) and the real cycle (thermal loss, pumping loss…).
Volumetric efficiency.
Engine-vehicle adaptation: Willans diagram, fuel consumption, gear staging.

ENGINE MECHANICS 1.5 d
Engine acyclism: reasons why an engine does not work regularly: forces due to gas pressure and inertia of moving parts. Consequences of acyclism (belt resistance, damper pulley, double flywheel clutch - DFC).
Balancing: use of a balancer shaft or a counterweight on a crankshaft. Inertia load due to rotary and alternative forces. Inertia load of first and second order (H1, H2) on a 4-cylinder engine.
Valve timing: how the different valve drives work.
Lubrication: the different lubrication modes. Viscosity. Stribeck curve.

INLET/EXHAUST PROCESSES - PERFORMANCES & FORCED INDUCTION 1.5 d
Fluid dynamics: Bernoulli equation, Saint Venant equation, sound velocity.
Gas exchange and flow processes: use of pressure waves in inlet and exhaust pipes to increase the volumetric efficiency.
Exhaust Gas Recirculation (EGR): uses of EGR, low pressure EGR, high pressure EGR.
Turbocharging: how it works, technology, turbo adaptation.

MATERIALS - MECHANICAL ENDURANCE 1.5 d
Characteristics of metal alloy steels used in engines: grey iron, ductile iron, steel, aluminum.
Mechanical properties: Young's modulus, minimum yield, shear rating. Analysis of the engine major parts whose material and manufacturing process must be chosen.

ENGINE PARTS DAMAGE MODES 1 d
Due to thermal problems: carbonization, loss of mechanical characteristics, intercrystalline corrosion, creep, melting.
Due to mechanical problems: plastic deformation, fracture, fatigue failure, Goodman diagram, impact of vibrations.
Due to thermo-mechanical problems.
Due to tribologic problems: lubrication, Stribeck curve, pitting, fretting, abrasive wear, adhesive wear, erosive wear, cavitation, scuffing, stick-slip.

VIBRATIONS 1 d
Transverse vibration, Eigen mode, resonance, damping.
Vibration measurement, sonogram, tracking.
The above training includes many practical exercises.

Reference: MOT/ICE-E Only available as an In-House course.
Contact: ml.contact@ifptraining.com
Base Engine Design

Engine Design ................................................................. p. 28
Engine Reliability ............................................................. p. 29
Engine Cooling & Environment ......................................... p. 30
Powertrain NVH ............................................................... p. 31
Engine Parts Design ........................................................ p. 32
**Engine Design**

**Level:** ADVANCED

**Purpose**
This course provides participants a deeper knowledge and competencies to design and use dimensioning criteria of reciprocating piston engines, particularly those for automotive applications.

**Audience**
Engineers and technical staff involved in the field of engines who wish to be in a position to make technical choices and components dimensioning.

**Learning Objectives**
Upon completion of the course, participants will be able to:
- choose the architectures of a new engine at pre-project stage: cubic inch displacement, bore-stroke ratio, cylinder head and block structures, timing drive,
- select and use the adequate criteria to develop the cam laws,
- use the main rules applied to block and cylinder head design,
- choose materials for the main engine components and explain their selection.

**Ways & Means**
Many applicative examples of the real life, dimensioning exercises managed by learners, focused cases study.

**Prerequisites**
IC Engine Fundamentals.

**Expertise & Coordination**
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

**Course Content**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCHITECTURE OPTIONS</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Specifications of a new engine. Determining the main dimensions: bore, stroke, cylinder spacing, depending on the specifications: MEP characteristics and piston mean velocity on engines of the same range. Global design process of mobile coupling system, crankcase-cylinders, cylinder head, timing.</td>
<td></td>
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</tbody>
</table>

| MOBILE PARTS DIMENSIONING | 1.5 d |

| CRANKCASE-CYLINDERS & LOWER CRANKCASE | 0.5 d |

| CYLINDER HEAD | 0.75 d |

| TIMING | 0.75 d |

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Reference: MOT/COMOT-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/COMOT. Please contact us for more information.
Engine Reliability

Level: ADVANCED

Purpose

This course provides an understanding of the physical phenomena causing engine parts damage, the phenomena being thermal, mechanical, thermo-mechanical or tribologic ones. The theoretical aspect is punctuated with examples of damaged parts - pictures or real parts.

Audience

Engineers and technical staff involved in design or testing, who need to know damaging and failure processes of engine components. People of Quality department or aftersales technical analysis may also be interested.

Learning Objectives

Upon completion of the course, participants will be able to:
- diagnose the possible origin of a damage problem of an engine component,
- talk with tests and laboratory specialists to direct parts analysis and the validation tests to be performed,
- suggest solutions likely to solve the problem.

Ways & Means

- Interactive training using a number of real components, pictures and videos.
- Real life analysis of failures of components, search for origin of failures, description of the deteriorating process.
- It is possible to manage this exercise on a component previously proposed by a learner, with a description of use conditions.

Prerequisites

IC Engine Fundamentals.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ENGINE PARTS DAMAGE MODES

Mechanical engineer tools, statistical aspects of reliability.
Thermal damage: coking, mechanical characteristic losses, intercrystalline corrosion, burnout, creeping, melting, lubricant viscosity drop.
Mechanical damage: plastic distortion, unshrinking, fracture or fatigue failure, vibration impact.
Thermo-mechanical damage: stresses caused by constrained metal expansion.
Tribologic ones: lubrication parameters, stribeck curve, pitting, micro-reptation, loosenning, fretting/micro-welding, abrasive wear, adhesive wear, erosive wear, cavitation, scuffing, seizing, stick-slip.

MOBILE PARTS DAMAGE

Conrods: failure modes, almost static stresses, dynamic stresses, buckling, screws resistance.
Crankshaft: quasi-static (gas pressures and inertia) and dynamic (flexion and torsion) stresses, strengthening treatments, roller-burnishing, dimensioning calculations, fatigue tests.
Bushing damage modes: fatigue, wear, cavitation wear, abrasive wear, scale and pollution wear, micro-welding, seizing.
Piston: distortions, ring sticking, skirt crush, seizing, stresses in the pin bosses.

FIXED PARTS DAMAGE

Ignition pressure and manufacturing related mechanical stresses (assemblies, shrink fitting, tightening).
Thermal stresses and thermo-mechanical constraints.
Cylinder head: cracking, materials, fire face behavior and solutions for its resistance, other critical points.
Exhaust manifold: mechanical and thermal stresses, materials, failures found, solutions.
Cylinder head gasket: stresses, failures, influence of the cylinder head and crankcase cylinders distortions, solutions.

COOLING

Heat transfers by conduction, convection, radiation, phase change. Thermal balance.
Thermics and engine cooling: levels of temperatures reached, critical points, cooling fluid circulation in the block and the cylinder head.
External cooling circuit: permanent branch, thermally regulated branch, pump, exchangers, thermostat, ventilating, cooling fluid, dimensioning.
Thermal measure means: thermo-couples, thermistors, flux meter, infrared pyrometry.

LUBRICATION

Lubricant cleanliness and consequences on wear.
Engine oil rheological behavior and change of properties in service:
   Oxidation thickening, soot, black sludge and consequences on cold starting.
   Viscosity decrease by polymer shearing or by dilution and consequences on warm engine.
Thermal and oxidation stability: cracking, thickening, deposits.
Timing lubrication.

Reference: MOT/FIMOT-E  Only available as an In-House course.

This course is also available in French: MOT/FIMOT. Please contact us for more information.

Contact: ml.contact@ifptraining.com
## Purpose

This course provides a deeper knowledge and competencies on engine thermal behavior and the vehicle energy management through “external” cooling systems.

## Audience

Engineers and technical staff from engine design and testing involved in thermal behavior and energy management, including cooling system designers.

## Learning Objectives

Upon completion of the course, participants will be able to:

- know the main associated stakes,
- implement a new engine in a new vehicle,
- quickly size the cooling system and suggest the required trade-offs.

## Ways & Means

- This training uses simple exercises of cooling system sizing, giving orders of magnitude.
- Clear progression from simple cooling loop up to very complex thermal management of hybrid electric vehicles.
- In parallel many components, new, used or faulty will be circulated.
- The last 0.5-day is dedicated to simulation of various in-use situations.

## Prerequisites

Engine fundamentals knowledge would be better.

## Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

## Course Content

<table>
<thead>
<tr>
<th>Module</th>
<th>Title</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td>ENGINE COOLING &amp; EXTERNAL CIRCUITS</td>
<td>0.4 d</td>
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<tr>
<td></td>
<td>Engine cooling requirements, cooling systems types, convection air system, induced air system, liquid system.</td>
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<tr>
<td></td>
<td>Automotive liquid cooling circuit architectures, engine internal component (water pump, thermostat), external components (exchangers, fans…), split-cooling, coolant, non-automotive applications.</td>
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<tr>
<td></td>
<td>IMPACT ON VEHICLE - HOW DO THE INTERNAL COMPONENTS WORK?</td>
<td>0.4 d</td>
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<tr>
<td></td>
<td>Cooling air circuit: air inlet, electric fan.</td>
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<tr>
<td></td>
<td>Coolant circuit: main radiator, engine oil cooler, transmission oil cooler, EGR cooler, passenger compartment heater core, charge air cooler, expansion tank, degassing tank.</td>
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<tr>
<td></td>
<td>CONTROL &amp; DRIVING - APPROACH TO ENERGY MANAGEMENT</td>
<td>0.5 d</td>
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<tr>
<td></td>
<td>Control parameters: temperature, pressure, flow.</td>
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<tr>
<td></td>
<td>Control units, sensors: thermostat, thermal switch.</td>
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<tr>
<td></td>
<td>Control units, actuators: driven thermostat, motorized shutters, multi-ways valves.</td>
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<tr>
<td></td>
<td>THERMOMANAGEMENT - THERMAL &amp; ENERGY MANAGEMENT</td>
<td>0.5 d</td>
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<tr>
<td></td>
<td>Objectives of thermal management. Different ways for thermal management: electric water pump, split-cooling, multiways valves, multi temperature loops, multi-fluids loops.</td>
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<tr>
<td></td>
<td>Strategies for thermal recovery: storage, exhaust calories recovery with a Rankine cycle, exhaust calories recovery with thermo-electricity.</td>
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<tr>
<td></td>
<td>THERMAL &amp; ENERGY MANAGEMENT OF HYBRID &amp; ELECTRIC VEHICLES</td>
<td>0.5 d</td>
</tr>
<tr>
<td></td>
<td>Objectives of the thermal management. Passenger cab thermal management: use conditions, critical conditions, impact on fuel economy, solutions.</td>
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<tr>
<td></td>
<td>Thermal management of electric components: objectives, solutions for thermal/electric hybrids, solutions for full electric vehicles.</td>
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<tr>
<td></td>
<td>UNDER HOOD THERMICS</td>
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<tr>
<td></td>
<td>Identification of heat sources, impact of exhaust gas after-treatment systems.</td>
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<tr>
<td></td>
<td>Temperatures, hot air flow, components protection through thermal barrier, convective cooling or liquid cooling. Passenger cab thermal insulation.</td>
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<tr>
<td></td>
<td>SIMULATION EXERCISES</td>
<td>0.5 d</td>
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<tr>
<td></td>
<td>Application of the above chapters. Sizing of the main cooling system components. Simulation of the most severe in-use situations (max speed, hill climbing with trailer, zero flow) with GT Power software. Choice of thermal strategy and components selection.</td>
<td></td>
</tr>
</tbody>
</table>

Reference: MOT/REFEM-E  
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/REFEM. Please contact us for more information.
**Powertrain NVH**

**Noise, Vibrations, Harshness**

**Level:** ADVANCED

**Purpose**

This course provides a deeper knowledge and competencies of the nature and origin of noises and vibrations generated in the powertrains and the measurement and analysis methods used in the vibro-acoustic field. It aims at implementing technical solutions to reduce noise and vibration.

**Audience**

Engineers and technical staff from engine design or testing involved in vibration physics on noise aspect as well as mechanical behavior.

**Learning Objectives**

Upon completion of the course, participants will be able to:

- know the parameters used to characterize noise and vibrations,
- understand vibrating systems behaviors and control parameters,
- know the signal processing instruments and methods,
- master experimental techniques,
- identify the acoustic signature of the powertrain’s (PT) main sources,
- interpret the sonograms corresponding to the main vibration sources of the powertrain,
- carry out a validation test on vibration for engine-related parts.

**Ways & Means**

Real and concrete examples of powertrain vibro-acoustic problems discussed by experts from the automotive world. Real and concrete solutions implemented in the industry.

**Prerequisites**

IC engine fundamentals.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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**Course Content**

**ACOUSTIC & VIBRATIONS IN THE INDUSTRIAL WORLD**

0.25 d

Acoustics: pressure, intensity, sound power; levels expressed in decibels, sound level structure; sound velocity. Time and space variations of waves, plane and spherical waves, propagation law. Human ear, hearing properties, ear sensitivity. A-weighting decibel levels. Vibration parameters analysis: acceleration, velocity, displacement. Free or forced response ringing oscillator, free-running frequency, role of damping.

**SIGNAL ANALYSIS INSTRUMENTS & METHODS**

0.5 d

Signals classification and processing; fast Fourier transformation (FFT): sampling, weigh time space, spectrum. Time analysis, spectral analysis, white noise, pink noise, order analysis. Tri-dimensional representations, sonograms, time-frequency representations. Acoustic phenomena measure instruments: microphones, displacement sensors, acceleration sensors, acoustic imaging, anechoic bench. Modal analysis (experimentations): vibration mode of a metal plate; structure response to a dynamic stress (loudspeaker, vibrator, unbalanced electric engine); deformation display with a stroboscope.

**POWERTRAIN NOISE VIBRATION & HARSHNESS**

0.75 d


Efforts of inertia: single-cylinder, three and four cylinder in-line engines dynamics; use of balancer shafts; composition of the combustion and inertia efforts; effect of dual mass flywheel (DMA). Combustion noise: cylinder pressure, dynamic pressure, spectral analysis of the cylinder pressure; technologies impact on the combustion noise; transfer and spread of combustion noise; measurement of combustion noise; combustion noise in transient operation.

**POWERTRAIN MAIN NOISES & VIBRATIONS**

0.75 d


**ACOUSTIC SIGNATURES OF THE POWERTRAIN (PT) MAIN SOURCES**

0.25 d

Acoustic and vibratory process during design: reduction at source or vibration filtration.

PT primary and secondary sources, glossary of the engine’s main sources. Examples of acoustic signatures (analysis from sonograms): diesel injector, supercharger, timing, belt-driven accessories, gearbox, starter, intake noise. Demonstrator: analysis of the noise sources of an electrically-driven thermal engine model; spectral analysis during a speed increase, interpretation.

**PARTS MECHANICAL RESISTANCE TO VIBRATIONS**

0.5 d

Validation of engine parts with all the vibration types: identifying the frequencies and the rates of generation of overvoltage and resonances, quantification of vibratory levels during acceleration and displacement, determining the endurance conditions and durations.

Examples: validation of an intake P/T sensor, of an oil gauge guide, of an oil turbo pipe.

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Reference: MOT/ACMOT-E. Only available as an In-House course.

This course is also available in French: MOT/ACMOT. Please contact us for more information.
Purpose
This course provides a deeper knowledge and competencies on metallurgy basics on ferrous and non-ferrous alloys, processes of foundry, forge, machining, plastic material implementation, used in the manufacturing process of automotive engine parts. It helps setting up physical and economic conditions in order to choose a manufacturing process.

Audience
Engineers and technical staff involved in automotive or industrial engines design, who need to know the manufacturing processes (materials, casting, forge, machining...).

Learning Objectives
Upon completion of the course, participants will be able to:
- take into account the constraints related to the different manufacturing processes when designing engine parts,
- choose the materials and the treatments, dimensional tolerances, surface roughness, shapes, clearance, assemblies, beading needed.

Ways & Means
- Interactive talks and illustrative videos.
- Real components to be examined.
- Videos of the different processes.

Prerequisites
IC engine fundamentals.

More info
This training adequately completes the training “Engine Design”.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Reference: MOT/COPIM-E  Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/COPIM. Please contact us for more information.
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Engine Measurements & Calibrations .................................................................................... p. 41
Engine Measurements Tests Analysis & Calibrations ............................................................. p. 42
Diesel Engines Performances - Level 1 ............................................................................... p. 43
Diesel Engines Performances - Level 2 ............................................................................... p. 44
New Combustion Systems in Spark Ignited Engines

Level: ADVANCED

Purpose
This course provides an understanding of direct or indirect injection SI engines: the physics of the mixture preparation, of the combustion and of the pollutants formation; as well as the influence of the engine setting parameters.

Audience
Engineers and technical staff who have to optimize SI engines’ combustion.

Learning Objectives
Upon completion of the course, participants will be able to:
► organize a series of tests,
► analyze the results in order to optimize combustion,
► know the evolution trends for the next 5 years.

Ways & Means
► Interactive talks.
► Many “up-to-date” examples and combustion videos.

Prerequisites
IC engines fundamentals.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

CURRENT TECHNOLOGIES & ASSOCIATED COMBUSTION SYSTEMS 0.75 d
Regulations: CO₂, particles, WLTP.
Current engine technologies, associated combustion systems, indirect injection (GII), direct injection (GDI), central jet spray, side jet spray, homogeneous combustion, stratified combustion, CAI.
Impact of air loops, variable timing.

GENERIC APPROACH OF COMBUSTION SYSTEMS (GII & GDI) 0.25 d
Normal combustions: turbulence, thermodynamical conditions, spark ignition.
Abnormal combustions: knocking, rumble, superknocking…
Valve timing, impact on combustion.

COMBUSTION SYSTEM DESIGN WITH INDIRECT INJECTION (GII) 1 d
Combustion chamber shape, ports design, injector targeting, rail pressure.
Warm phase combustion.
Cold phase combustion.

COMBUSTION SYSTEM DESIGN WITH HOMOGENEOUS DIRECT INJECTION LAMBDA = 1 0.5 d
Central jet spray, side jet spray, combustion chamber shape.
Injector targeting.
Injection system, injection strategies, multiple injections.
Particles, dilution.
Warm phase combustion.
Cold phase combustion.

TECHNICAL EVOLUTIONS 0.5 d
Impact of combustion optimizing on architecture choice: 2, 3, 4 cylinders.
International context (RON, intake spooling, flex-fuel…).
Technical evolution in 2020 view.

Reference: MOT/COMBE-E
Only available as an In-House course.
Contact: ml.contact@ifptraining.com
This course is also available in French: MOT/COMBE. Please contact us for more information.
New Developments in Spark-Ignition Engines

Course Content

**COMBUSTION IN GASOLINE ENGINES**

How does a spark engine work?
Chemical reaction equation, stoichiometric air/fuel ratio, equivalence ratio, specific heat value.
Residual exhaust gas and influence on combustion and emissions.
Influence of pumping losses and friction losses on brake specific fuel consumption (BSFC). Unburnt hydrocarbons: why they are found in the exhaust and how reducing them.

**GASOLINE CHARACTERISTICS**

Market evolution and sharing among the different gasoline fuels.

**AIR SUPPLY - PERFORMANCES & FORCED INDUCTION**

Air supply: pressure waves in inlet and exhaust ducts, influence on volumetric efficiency and on full load performance. Design of intake/exhaust valves to optimize volumetric efficiency (1/4 waves…).
Performances: potential of each technology, parameters affecting the performances.

**TECHNOLOGY**

Gasoline Direct Injection (GDI):
GDI advantages and drawbacks. Operational strategies (stoichiometric, stratified…).
Components-injectors system, HP pump, regulator, fuel supply, power supply. GDI systems.
Variable Valve Actuation (VVA):
Classical valve actuation: principles, limits.
Variable valve actuation: advantages compared with conventional valve actuation, classification.
Current technologies: variable valve timing systems, 2-step systems (Honda VTEC, Porsche-INA variocam), continuous systems (BMW valvetronic), camless systems (FEV-Valeo).
Downsizing:

**EXHAUST GAS AFTER-TREATMENT**

Three-way catalyst (TWC): efficiency versus relative air/fuel ratio, oxygen storage capacity (OSC), structure and manufacturing, light-off temperature, ageing.
NOx Trap.

**ENGINE MANAGEMENT SYSTEM**

Functions of the engine management system, sensors, actuators, strategies: air flow control by electrical engine actuated throttle; fuel injection, air flow measurement or calculation, relative air fuel ratio closed loop control by single or dual oxygen sensor (lambda probe); speed and crankshaft angular position measurement; spark ignition timing, anti-knock strategy; canister control diagnostic.

Level: **FOUNDATION**

**Purpose**

This course provides a better technical knowledge of spark ignition engines, in order to help people working on a specific problem to communicate efficiently with every person involved, whichever field they’re from.

**Audience**

Engineers and technical staff involved in the design, development and testing of spark-ignition engines and equipment.
Well adapted to training abroad.

**Learning Objectives**

Upon completion of the course, participants will be able to:
- know the main characteristics required for a good gasoline engine behavior,
- know normal and abnormal combustion mechanisms,
- understand the influence of engine tuning parameters on combustion and pollutant emissions,
- understand the influence of engine design parameters on volumetric efficiency and full load performances,
- know the advantages of Gasoline Direct Injection (GDI) and downsizing,
- know the principles of forced induction systems and developments,
- choose after-treatment systems to reduce exhaust emissions: Three-Way Catalyst (TWC), NOx Trap,
- know engine control systems: sensors, actuators, strategies.

**Ways & Means**

- Various interactive talks, adapted to the participants’ fields of activity.
- Videos.

**Prerequisites**

No prerequisites for this course.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Reference: **MOT/MOTE-E**  
Only available as an In-House course.

Contact: **mt.contact@ifptraining.com**

www.ifptraining.com
# New Combustion Developments in Diesel Engines

## Level: ADVANCED

### Purpose

To understand, in Diesel engines:
- the role of the injection system and of aerodynamics in the cylinder on the air-fuel mixture,
- the mechanisms of the mixture inflammation, of combustion and of pollutants formation,
- the influence of the engine tuning parameters on performances, efficiency and emissions,
- the turbocharger behavior.

### Audience

Engineers and technical staff who have to optimize Diesel engine combustion.

### Learning Objectives

To be able to organize a series of tests and to analyze the results in order to optimize:
- the combustion system (injection system, internal aerodynamics, combustion chamber geometry),
- the engine tuning parameters (advance, injection pressure, multi-injections, exhaust gas recirculation).

### Ways & Means

Practical aspects come with dimensioning and matching simulation exercises.

### Prerequisites

IC engines fundamentals.

### Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

### Course Content

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FUEL JET INFLAMMATION</strong></td>
<td>Diesel engine history. Diesel combustion stages. Self-inflammation delay, basic knowledge on cold flames, influence of the different temperature, pressure, air-fuel ratio, residual gas parameters. Pre-mixture flame and diffusion flame combustions. Soot formation and oxidation mechanisms, nitrogen oxides and carbon monoxide formations. Jet structure during combustion.</td>
<td>0.5 d</td>
</tr>
<tr>
<td><strong>AERODYNAMICS - SWIRL GENERATION &amp; MEASUREMENT</strong></td>
<td>Interference between the swirl and the squish. Influence on the air-fuel mixture and on combustion. Defining the swirl number and the cylinder head permeability. Bowl shape in the piston.</td>
<td>0.25 d</td>
</tr>
<tr>
<td><strong>INJECTION SYSTEMS</strong></td>
<td>Injectors nozzles, injector holes flow rate coefficient, hydraulic flow rate. Exercise: determining a hydraulic flow rate. Common-rail injection systems technologies: solenoid control (balanced or unbalanced electrovalve), piezo-electric control, 2-way and 3-way valves, direct piezo control, pressure amplification systems.</td>
<td>0.25 d</td>
</tr>
<tr>
<td><strong>HOMOGENEOUS CHARGE COMPRESSION IGNITION (HCCI)</strong></td>
<td>Operating principle, interest, examples of developments. Critical points: operating area without NOx formation, HC and CO emissions, high load operating, combustion control. Technologies to be implemented to optimize the concept as a whole: combustion system, exhaust gas after-treatment, engine control (acting on the exhaust gas recirculation, the turbocharger, the inlet temperature, the variable timing).</td>
<td>0.5 d</td>
</tr>
</tbody>
</table>

Reference: MOT/COMBD-E  Only available as an In-House course.  
Contact: ml.contact@ifptraining.com
Exhaust Gas After-Treatment

Level: ADVANCED

Purpose
This course provides a deeper knowledge on relations between Diesel and SI engines and air quality.

Audience
Engineers and technical staff who want to know current and future exhaust gases after-treatment systems.

Learning Objectives
Upon completion of the course, participants will be able to:
- understand the contribution of alternative engines to atmospheric pollution phenomena,
- know the emissions regulations,
- know the nature of the emitted pollutants,
- use emission reduction levers at source,
- understand Diesel and SI engines depollution systems’ operations, in relation with the combustion mode,
- choose depollution strategies and select after-treatment systems.

Ways & Means
Industry experts manage computerized Matlab Simulink simulations on real life data.

Prerequisites
MOT/MOT1-E or MOT/MOT3-E, as well as MOT/COMBE-E or MOT/COMBD-E, are a good basis to MOT/PTGE-E.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

OXIDATION & TRI-FUNCTIONAL CATALYSIS
Automotive exhaust catalysis: catalytic reactions, mechanisms, catalysts, noble metals, performance criteria, functional definitions (conversion rate, after-treatment related constraints, gasoline and diesel).
Catalysts structure: catalytic converter industry, initiation, conversion rate, case of methane, active substances.
Oxidation catalysis: efficiency, field, initiation, conversion rate, case of methane, sulfur and particles oxidation.
Tri-functional catalysis: stoichiometric conditions, air/fuel ratio control, cold conditions (HC, exhaust thermal management), high power loop opening.
Catalysts ageing: ageing nature, thermal (temperature and sintering), chemical (poisoning), by the accumulation of deposits coming from the lubricants, the fuels or the additives. Functional limit of catalysts ageing.
On Board Diagnostics (OBD), prospects and conclusions.

NITROGEN OXIDES TREATMENT
NOx traps: operating principle (storage mechanisms, range of temperatures to use, rich mixture reduction phase), trap desulfurization.

DIESEL PARTICULATES FILTER - DPF
Filtration element structure and composition regeneration strategy either by fuel additive, Fuel Born Catalyst, or by Catalytic Diesel Particulates Filter (CdPF). Use of the 5th or the 7th injector.
Installation on the vehicle
Evolution towards the 4-way catalysis: in the same converter, combining the particulates filter of a nitrogen oxides treatment system (SCr or non-trap) with an oxidation catalyst.

OPTIMIZATION BY SIMULATING A DIESEL EXHAUST LINE
(practical on Matlab Simulink)
An example of diesel exhaust line including a Diesel Oxidation Catalyst (DOC) as well as a Diesel Particulate Filter (DPF) will serve as the basis for introducing after-treatment systems modeling/simulation. Participants will be taught how calculations can replace a long series of tests and focus the validation tests to the strict necessary. Different digital tools will be analyzed then implemented to optimize the line. The input data being known (temperature and gas flow at DOC intake, at source engine emissions), several scenario will be simulated to optimize:
- the catalyst volume and precious metals load
- the hydrocarbons quantity to be post-injected to the exhaust line to make sure the DPF will be regenerated.
The practical will make it possible for participants to understand the physics found in the model: thermal balance, pollutants mass balance, chemical reactions kinetics on load and speed transients.

Reference: MOT/PTGE-E
Only available as an In-House course.

Contact: ml.contact@ifptraining.com
This course is also available in French: MOT/PTGE. Please contact us for more information.

Reference: MOT/PTGE-E
Only available as an In-House course.

Contact: ml.contact@ifptraining.com
This course is also available in French: MOT/PTGE. Please contact us for more information.

www.ifptraining.com
New Developments in Diesel Engines

**Level:** FOUNDATION

**Purpose**
This course provides a deeper knowledge on diesel engine combustion and depollution, diesel fuels, high-pressure injection systems, turbocharging, and exhaust treatment systems.

**Audience**
Engineers and technical staff involved in the design, development, and testing of diesel engines and equipment. Well adapted to training abroad.

**Learning Objectives**
Upon completion of the course, participants will be able to:
- understand the mechanisms of pollutants formation and the trade-off between emissions, performance, fuel consumption, durability, cold starting, and drivability.
- know the evolution of Diesel combustion and exhaust gas recirculation systems and how to optimize them.
- know the main fuel properties required for a good engine performance.
- know the evolution of fuel injection systems and turbocharger technologies.
- know the exhaust gas after-treatment systems and strategies used on current and future engines.

**Ways & Means**
- Various interactive talks, adapted to the participants' fields of activity.
- Videos.

**Prerequisites**
No prerequisites for this course.

**Expertise & Coordination**
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

**Course Content**

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### DIESEL COMBUSTION OPTIMIZATION

#### 2.25 d

- Automotive industry in the world.
- Approaches net classifications to define and design a powertrain.
- How does a spark engine work?
- Engine to wheel: air-fuel mixture, burn the air-fuel mixture, transformation into mechanical energy in the wheels.
- Chemical reaction equation, stoichiometric air/fuel ratio, equivalence ratio, specific heat value.
- Influence of tuning parameters: air-fuel ratio, fuel injection timing, fuel-air mixture efficiency, temperature, injection pressure.
- Optimization of swirl, bowl in the piston, spray-holes position and diameter. Fuel spray characteristics.
- New combustion process: homogeneous charge compression ignition (HCCI), advantages and drawbacks.

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### DIESEL FUELS CHARACTERISTICS

#### 0.25 d

- Ignition delay and self-ignition ability: cetane rating.
- Cold flow characteristics: cloud point, cold filter plugging point, pour point.
- Lubricating properties, HFrr test, sulfur content.

---

### INJECTION SYSTEMS

#### 0.75 d

- Nozzle holes manufacturing and characterization: discharge coefficient, effective flow area, hydraulic flow.
- Hydroground conical holes.
- Classification of current cam-driven and common-rail systems. Comparison between unit-injector and common-rail systems.
- Evolution of high pressure pump, common-rail solenoid and piezo injectors.
- Temperature control in low pressure circuit.

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### TURBOCHARGING

#### 0.75 d

- Compressor and turbine field.
- Compressor and turbine dimensioning to match a given engine.
- Waste-gate, variable geometry turbine, parallel or sequential dual turbocharger.

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### EXHAUST GAS AFTER-TREATMENT

#### 1 d

- Evolution of emissions regulations for passenger cars and heavy trucks.
- Oxidation catalysts: structure, light-off temperature, conversion rate, ageing; diesel particulate filter (dPF): structure, trapping efficiency, regeneration with fuel additive (FBC: fuel born catalyst) or catalyzed filter (CdPF).
- Regeneration strategy, fifth or seventh injector, influence on oil drain intervals.
- NOx trap: operating principle, efficiency, limits.
- Selective catalytic reduction (SCR) with urea: principle, installation on heavy trucks, advantages and drawbacks.

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Reference: MOT/MOTD-E  
Only available as an In-House course.

Contact: ml.contact@ifptraining.com
Loading & Supercharging

Level: ADVANCED

Purpose

This course provides a deeper knowledge of engine loading and how they affect mouth noise, and the ways to improve engine loading or to choose air supply systems.

Audience

Engineers and technical staff from engine design or testing or from engine project teams wishing to understand the ways to improve engine loading or to choose air supply systems.

Learning Objectives

Upon completion of the course, participants will be able to:

- explain the intake and exhaust pressure losses and pressure wave losses phenomena, which govern the engine air loading and how they affect mouth noise;
- identify the reactions of the engine and turbocharger systems depending on the conditions of use.

Ways & Means

- Interactive training with real life examples.
- Practical approach is provided by design and matching exercises.

Prerequisites

No prerequisites for this course.

More info

This program can be extended by modeling and simulation and more knowledge about supercharging technologies, choose the next page course “Advanced filling and supercharging modeling and simulation” REMPS.

Expertise & Coordination

Trainer with a level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ENGINE AIR LOADING

Characteristic sizes: volumetric efficiency, delivery efficiency.

Elementary phenomena that govern discharge.

Pressure losses: Bernoulli equation, equivalent section, relative share of each element of the intake circuit, measurement on stationary test bench, influence on full load engine performances.

Acoustic intake.

Use of pressure waves to improve loading: mono-cylinder (high speed) or multi-cylinder (low speed) typed acoustic modes. Use of parameters without dimension (Broome number) to characterize the wave phase difference and amplitude. Acoustics and pressure losses trade-off.

Multi-cylinder engine optimization: influence of the cylinders number, the elements of the intake circuit upstream of the plenum. Variable acoustics: variation of the pipes length, volumes trade-off with pressure losses. Use of acoustic phenomena on turbocharged engines.

Trade-off between the mouth noise generated by pressure pulsations and performances.


Timing: optimizing the opening and closing angles and of the lift law forms of intake and exhaust valves. Variable timing: different types, interest.

TURBOCHARGING

Supercharging benefit and limits: use of the exhaust gas energy, increase in the engine power but also in cylinder pressures, thermal constraints; need to be able to make turbine permeability change by waste-gate or variable geometry.


Matching a turbocharger to a given engine: exercise in classroom.

Determining air flow rate and density at cylinder head inlet, calculating the corrected flow, choosing the compressor, calculating the compressor driving power, calculating the expansion ratio and choosing the turbine, calculating the flow in the waste-gate, choosing a variable geometry turbine, case of operating at altitude.

Twin turbocharging: different assembly types, interest, drawbacks.

Reference: MOT/REMP-E

Only available as an In-House course.

This course is also available in French: MOT/REMP. Please contact us for more information.

Contact: mt.contact@ifptraining.com

www.ifptraining.com
Advanced Loading & Supercharging Modelings, Simulations & Analyses

Level: ADVANCED

Purpose
This course provides a deeper knowledge on the air supply of atmospheric, turbocharged and supercharged engines in order to improve specific performances, as well as on engine supercharging architectures such as twincarging. This program improves the training course “Loading & Supercharging” by the addition of new items: supercharging and volumetric wave systems, twinccharging architectures, turbocharging acoustics, modeling and simulation.

Audience
Engineers and technical staff from engine design or testing or from engine project teams wishing to understand the ways to improve engine loading, to choose a turbocharger or supercharging solutions. Engineers and technical staff wishing to improve their knowledge of new architectures and model based design.

Learning Objectives
Upon completion of the course, participants will be able to:
- explain the intake and exhaust pressure losses and pressure waves losses phenomena, which govern the engine air loading and how they affect mouth noise,
- realize the building actions (shapes and dimensions of inserts, intake and exhaust volumes, setting of the valve-lift laws), aiming at optimizing loading, illustrated by examples of simple calculations,
- determine a turbocharger for a given application, illustrated by an example to be handled by the participants,
- identify the reactions of the engine and turbocharger systems depending on the conditions of use,
- explain the choice of new supercharging architectures (twinccharging, series or parallel supercharging...),
- modelize and simulate intake air and exhaust gases acoustic phenomena,
- modelize and simulate supercharging components: compressors, wave compressors, turbochargers,
- modelize and simulate supercharging architectures,
- design air and supercharging circuits.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ENGINE AIR LOADING
1.5 d
Characteristics sizes: volumetric efficiency, delivery efficiency.
Elementary phenomena that govern discharge.
Pressure losses: Bernoulli equation, equivalent section, relative share of each element of the intake circuit, measurement on stationary test bench, influence on full load engine performances.
Acoustic intake
Use of pressure waves to improve loading; mono-cylinder (high speed) or multi-cylinder (low speed) typed acoustic modes. Use of parameters without dimension (Broome number) to characterize the wave phase difference and amplitude. Acoustics and pressure losses trade-off.
Multi-cylinder engine optimization: influence of the cylinders number, the elements of the intake circuit upstream of the plenum.
Variable acoustics: variation of the pipe lengths, volumes trade-off with pressure losses. Use of acoustic phenomena on turbocharged engines.
Trade-off between the mouth noise generated by pressure pulsations and performances.
Timing: optimizing the opening and closing angles and of the lift law forms of intake and exhaust valves. Variable timing: different types, interest.

TURBOCHARGING
1.5 d
Supercharging benefit and limits: use of the exhaust gas energy, increase in the engine power but also in cylinder pressures, temperatures, thermal constraints; need to be able to make turbine permeability change by waste-gate or variable geometry.
Determining air flow rate and density at cylinder head inlet, calculating the corrected flow, choosing the compressor, calculating the compressor driving power, calculating the expansion ratio and choosing the turbine, calculating the flow in the waste-gate, choosing a variable geometry turbine, case of operating at altitude.
Twin turbocharging: different assembly types, interest, drawbacks.

SUPPLEMENTS TO TURBOCHARGING
0.5 d
Other compressors. Superchargers and wave compressors (technology, characteristics and interests). Use in modern vehicle architecture.
Supercharging architectures: series and parallel twinccharging; volumetric compressors. Acoustic of supercharged engines.

LOADING & SUPERCHARGING MODELING & SIMULATION
1.5 d
Fundamentals of air system 1D modeling and simulation.
Components modeling: pipes, volumes, junctions, valves, compressors, turbochargers and superchargers.
Case studies of main engine architectures with GT-Power models: atmospheric engines, supercharged diesel engines. Ignition engine with single and twincarging: supercharger and turbocharger.

Reference: MOT/REMPS-E
Only available as an In-House course.
Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/REMPS. Please contact us for more information.
Engine Measurements & Calibrations

Level: ADVANCED

Purpose

This course provides an understanding of the "how" and "why" of measurements, their use for development and calibration of spark ignition and diesel engines.

Audience

Engineers and technical staff making or using measurement equipment for the purposes of tuning in order to better understand the measurement and equipment, the calibration process and the risks of wrong results interpretation.

Learning Objectives

Upon completion of the course, participants will be able to:

- know the fundamentals of engines’ tuning, calibration and associated tests,
- know the types of measurements and means necessary for engine calibration,
- know the pattern of an engine development and the associated measurements,
- know the major types of tests and measurements necessary for engine and vehicle development,
- understand the tests on track and the customer requirements,
- understand the structures of the different engine test bench types and how to drive and monitor them,
- know the measurement methods called "slow" such as speed, torque, temperatures, pressure, flows, gas analysis,
- know the instantaneous measurement methods such as in-cylinder pressure and how to use them in combustion analyses,
- use the classical gas sampling and analyses,
- set the main rules of a test campaign,
- identify dysfunctions to avoid misinterpretation.

Prerequisites

It is recommended to have a basic understanding of the internal combustion engines operation.

More info

This program can be improved with studies on virtual engine test benches in order to better understand the measurement and equipment, the calibration process and the risks of wrong results interpretation.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

INTRODUCTION TO THE ENGINE TUNING & CALIBRATION

Different benefits to consider: basic settings, performance, cold operation, depollution/standards to be met, particulate filter regeneration, OBD diagnostics. Impact of drifts and dispersions, ambient conditions. The engine operating points. Main parameters of engine tuning.

STATIONARY ENGINE DYNO TEST BENCH MEASUREMENTS

Tests carried out on stationary engine dyno test benches: reliability tests of engine components or after-treatment systems, architecture development tests (friction, thermal, fluid circuits) or engine control development tests. Driving and monitoring system of an automated test bench. Slow measurements: cooling circuit (temperature, pressure, flow), stability criteria, parts thermo-mechanical resistance tests; oil and fuel circuits (pressure and temperature control, consumption measurement); air circuits (temperature and hygrometry regulation, mass and volume flow meters); load machine, torque and speed measurement.

Instantaneous measurements: measurement and acquisition of cylinder pressure, intake and exhaust instantaneous pressures, angular encoding, combustion analysis.

Virtual engine test bench tour.

ENGINE TEST BENCH MEASUREMENTS ANALYSIS

Validation process of a test by results analysis, comparison with the expected results. How to determine the reasons of a non-validation.

SPECIAL VEHICLE TEST BENCH

Equipment, instrumentation, measurements goals from the tuning point of view

- Climatic room.
- Evaporation room.
- Altimeter bench.
- Aero-climate bench.

Tests on track, on cycles, in extreme conditions, customer requirements.

Virtual bench tour.

MEASUREMENTS OF NON REGULATED POLLUTANTS & OF PARTICLES GRANULOMETRY

Measurements of non regulated pollutants (NrP): HC, aldehydes, NH3, HAP.

Particles granulometry: electrical low pressure impactor (ELPI), Scanning mobility Particle Sizing (SMPS).

Difficulties to interpret the measurements results. Dynamic mass measurements (TEOM, Micro Soot Sensor).

SAMPLING METHODS AT ENGINE DYNO & ROLLER TEST BENCHES

Hot or cold samples, wet or dry gas analysis.

Constant flow dilution system (Constant Volume Sampling).

Full or partial flow systems, advantages and drawbacks.

CLASSICAL METHODS OF GASEOUS POLLUTANTS & PARTICLES MEASUREMENTS

Nitrogen monoxide and dioxide measurement with infra-red absorbing detector.

Nitrogen oxides measurements with chemico-luminescence.

Oxygen measurement with paramagnetic detector.

Unburnt hydrocarbons measurement with flame ionization detector.

Particles measurement with gravimetric method, smoke meter, opacity meter.

GAS ANALYSIS BY FOURIER TRANSFORM INFRARED (FTIR) & ULTRAVIOLET (FTUV)

Measurement principle, use of spectrometer, analyzed gas.

Advantages compared with other methods: response time, wet hot gas sampling, lack of calibration with titer gas, results obtained.

NUMERICAL METHODS FOR ENGINE TUNING & CALIBRATIONS

Definition of the cycle operating points. Engine parameters impact on tuning methodologies and numerical approach. Definition of DoE: choices of operating points, parameters, measures and measuring instruments.

Numerical models identification. Optimization of the calibration according to requirements (consumption, emissions, noise, approval, performance). Optimization methodologies.

Reference: MOT/MBM-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/MBM. Please contact us for more information.

www.ifptraining.com
 Engine Measurements Tests Analysis & Calibrations

Level: ADVANCED

Purpose
This course provides a better understanding of the “how” and “why” of measurements, their use for development and calibration of spark ignition and diesel engines.
To know the fundamentals, the limitations and the results that can be expected from different measuring devices used on engine or vehicle benches. To identify and calculate the measurement uncertainties.

Audience
Engineers and technical staff making or using engine measurements in order to improve measurements, calibration process, engine tuning, risks of wrong results interpretation and interested in learning engine operating parameters behavior.

Learning Objectives
Upon completion of the course, participants will be able to:
- know the fundamentals of engines’ tuning, calibration and associated tests,
- know the types of measurements and means necessary for calibration,
- understand the structures of the different engine test bench types, how to drive and monitor them, in relation with the engine control system,
- use the classical gas sampling and analyses,
- identify dysfunctions (engine or bench) to avoid misinterpretation,
- practice a virtual diesel engine test bench: to conduct fundamental tuning, to measure main operating parameters, to analyze measurements and optimize calibrations,
- understand main engine parameters behavior.

Ways & Means
- This training combines theoretical knowledge and know-how applied to numerical simulator using spark ignition and diesel engines test benches.
- The participant can experience the “how” and “why” of engine measurements to better understand tuning methodologies.
- Real case studies with numeric simulation.
- Examples of heat balance and test development from real cases.

Prerequisites
No prerequisites for this course.

More info
It is recommended to have a basic understanding of the internal combustion engines operation.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

INTRODUCTION TO THE ENGINE TUNING & CALIBRATION
Different benefits to consider: basic settings, performance, cold operation, depollution/standards to be met, particulate filter regeneration, OBD diagnostics. Impact of drifts and dispersions, ambient conditions. The engine operating points. Main parameters of engine tuning.
0.5 d

STATIONARY ENGINE DINO TEST BENCH MEASUREMENTS
Tests carried out on stationary engine dyno test benches. Driving and monitoring system of an automated test bench. Slow measurements.
Instantaneous measurements. Virtual engine test bench tour.
0.5 d

ENGINE TEST BENCH MEASUREMENTS ANALYSIS
Validation process of a test by results analysis, comparison with the expected results. How to determine the reasons of a non-validation.
0.25 d

SPECIAL VEHICLE TEST BENCH
Equipment, instrumentation, measurements goals from the tuning point of view: climatic room, actuation bench, evaporation room, altimeter bench, aero-climate bench, tests on track, on cycles, in extreme conditions, customer requirements, virtual bench tour.
0.25 d

MEASUREMENTS OF NON REGULATED POLLUTANTS & OF PARTICLES GRANULOMETRY
Measurements of non regulated pollutants (Np): HC, aldehydes, NH₃, HAP. Particles granulometry: electrical low pressure impactor (ELPI), Scanning Mobility Particle Sizing (SMPS); difficulties to interpret the measurements results; dynamic mass measurements (TEDM, Micro Soot Sensor).
0.25 d

SAMPLING METHODS WITH ENGINE DINO & ROLLER TEST BENCHES
Hot or cold samples, wet or dry gas analysis. Constant flow dilution system (constant volume sampling). Full or partial flow systems, advantages and drawbacks.
0.25 d

CLASSICAL METHODS OF GASEOUS POLLUTANTS & PARTICLES MEASUREMENTS
0.25 d

GAS ANALYSIS BY FOURIER TRANSFORM INFRARED (FTIR) & ULTRAVIOLET (FTUV)
Measurement principle, use of spectrometer, analyzed gas. Advantages compared with other methods: response time, wet hot gas sampling, lack of calibration with titer gas, results obtained.
0.25 d

NUMERICAL METHODS FOR ENGINE TUNING & CALIBRATIONS
Definition of the cycle operating points. Engine parameters impact on tuning methodologies and numerical approach. Definition of DoE: choices of operating points, parameters, measures and measuring instruments. Numerical models identification. Optimization of the calibration according to requirements (consumption, emissions, noise, approval, performance). Optimization methodologies.
0.5 d

VIRTUAL SPARK I l gINATION ENGINE TEST BENCH
The proposed simulator is a virtual spark ignition engine test bench on which virtual testing will be conducted by varying the parameters to show their impact. Many measurements are performed on the engine. Simulator, characterization of full load operation and constant speed: optimal advance determination; power curve and maximum torque characteristics, specific fuel consumption, engine air load analysis; impact of test conditions (temperature and atmospheric pressure) on engine performances; spark advance analysis, CA50, ESC, ISC, engine performances, burning time evolution, injection time, exhaust temperature evolution. .
Variable distribution interest: Miller and Atkinson cycle at partial load; performance gain, ESC and pollutants; full load and partial load performances; torque characteristic analysis with an engine dynamometer.
1 d

VIRTUAL DIESEL ENGINE TEST BENCH
Simulator, characterization of a full load engine: determination of optimal settings, power and torque curve development, specific fuel consumption, air load analysis; test conditions impact on engine performances. Simulator, engine cycle operating points characterization: main parameters (injection pattern, rail pressure, EGR rate, boost pressure); analyzes on CA50, ESC, ISC, engine performance, emissions, combustion noise.
1 d

Reference: MOT/MEMS-E
Contact: ml.contact@ifptraining.com

1 This course is also available in French: MOT/MEMS. Please contact us for more information.
Diesel Engines Performances - Level 1

### Purpose
This course provides a deeper knowledge on heavy duty truck engines performances, design and development: basic sizes, combustion, injection systems, supercharging, fuels and lubricants.

### Audience
Engineers and technical staff working in relation with engine departments and needing to know the vocabulary, the physics fundamentals and the main technologies of Diesel engines.

### Learning Objectives
Upon completion of the course, participants will be able to:
- know the definition and the use of parameters used in the engine design and development,
- master the physics that lead to pollutants formation (PM, NOx, HC, CO) and the physics of the technologies aimed at reducing the pollutants (injection, swirl, exhaust gas recirculation, advance),
- understand the technologies of the injection systems used.
- know turbochargers' operating principles and the way to match them to an engine.

### Ways & Means
The fundamentals of Diesel engines in a funny and easy way for a better and reliable understanding.

### Prerequisites
No prerequisites for this course.

### Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

### Course Content

#### EFFICIENCY & PERFORMANCES 0.5 d
Power, torque, mean effective pressure, piston mean velocity: situation of heavy truck engines compared with the other spark ignition or Diesel engines.

Volumetric efficiency, influence on performances.


#### DIESEL COMBUSTION & INJECTION 1 d
Diesel combustion mechanism. Pollutants formation: PM, NOx, HC, CO. Representation on Pischinger diagram.

Different combustion phases: auto-inflammation delay, pre-mixture combustion, diffusion flame combustion.

Combustion-related noise. Fuel cetane number.

Combustion system: swirl definition, measurement and generation; fuel-jet characteristics: introduction rate, penetration, atomization, external form; piston combustion chamber.

Technology of the different injection systems: injectors-pumps, unit pumps, common-rail, Caterpillar system.

Exhaust gas recirculation: how it acts on nitrogen oxides reduction, interest of EGR cooling, development technologies.

New Diesel combustion processes (HCCI).

#### FUELS - LUBRICANTS 0.25 d
Fuel production in refineries. Diesel fuel main characteristics in relation with the use of engine: cetane, cold engine operability, distillation, lubrication capacity.

Lubricant main required properties.

#### SUPERCHARGING 0.25 d
Turbocharger operating principle.

Choosing a turbocharger to match a given engine.

Variable geometry turbocharger, twin scroll turbocharger.

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This course is also available in French: MOT/PMD1. Please contact us for more information.

Reference: MOT/PMD1-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

www.ifptraining.com
Diesel Engines Performances - Level 2

**Course Content**

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<th>Topic</th>
<th>Duration</th>
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<tr>
<td><strong>ATMOSPHERIC POLLUTION &amp; REGULATIONS</strong></td>
<td>0.25 d</td>
</tr>
<tr>
<td>Atmospheric pollution, main impacts on health, share of transports. Pollutants emitted by engines (regulated and non regulated). Regulations related to the vehicles exhaust emissions.</td>
<td></td>
</tr>
<tr>
<td><strong>EFFICIENCY &amp; PERFORMANCES</strong></td>
<td>0.25 d</td>
</tr>
<tr>
<td><strong>LUBRICANT</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td>Engine oils SAE viscosity classification. Diesel engine oils EPI and ACEA classifications. Problems of the diesel and engine and the lubrication: lubricant behavior with the soot (dispersion); fuel sulfur content (TNB and ashes content); cylinder resurfacing, lubricant compatibility with after-treatment systems (DPF). Oil filtration. Follow-up of in-service lubricants.</td>
<td></td>
</tr>
<tr>
<td><strong>DIESEL FUEL</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td><strong>DIESEL COMBUSTION &amp; INJECTION</strong></td>
<td>1.5 d</td>
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<tr>
<td><strong>AFTER-TREATMENT</strong></td>
<td>0.5 d</td>
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<tr>
<td><strong>SUPERCHARGING</strong></td>
<td>1.5 d</td>
</tr>
<tr>
<td>Turbochargers operating principle: compression and expansion energies, geometric characteristics, flow adjustment, cooling. Compressor pressure-flow map and operating limits (pumping, speed, efficiency). Turbine characteristics, saturation. Technologies of the turbocharger different parts: materials, lubrication, reliability aspects. Twin-scroll, variable geometry, dual supercharging turbochargers. Matching a turbocharger to an engine: choice of the compressor and of the turbine depending on the engine characteristics and performances. Participants will carry out a practical exercise of turbocharger adaptation.</td>
<td></td>
</tr>
</tbody>
</table>

**Ways & Means**

MOT/PMD1-E + MOT/PMD2-E give a full overview of the field of Diesel truck engines, through interactive talks and numerical exercises.

**Prerequisites**

MOT/PMD1-E training.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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Reference: MOT/PMD2-E  Only available as an In-House course. Contact: mi.contact@ifptraining.com

This course is also available in French: MOT/PMD2. Please contact us for more information.
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<td>Introduction to Engine Management: Practical Approach by Modeling &amp; Simulation</td>
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Module 4: Introduction to Engine Management

Level: FOUNDATION

Purpose
This course provides a deeper knowledge on strategies used to manage the engine operation in order to improve performances.

Audience
Engineers and technical staff from design and testing departments wishing to discover the engine management. It is recommended to initially follow modules 1, 2 & 3.

Learning Objectives
Upon completion of the course, participants will be able to:
- know engine control basics,
- determine and to carry out SI and Diesel engines set torque, by air, timing and fuel management,
- know depollution and OBD strategies necessary to meet the standards.

Ways & Means
Conventional talk with applied examples and describing the limits to physics.

Prerequisites
- It is recommended to previously follow MOT/MOT1-E, MOT/MOT2-E and MOT/MOT3-E.
- This training requires a basic knowledge related to the components of engine control, as offered in module 2 "Spark Ignition Engines" and module 3 "Diesel Engines".

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content
3 days

ENGINE MANAGEMENT BASES
Stakes, definitions, architectures.
- Automatisms: PID regulators (principle, tuning, gasoline idle speed and Diesel EGR control), new tuning methods and prospects.
- Diesel and gasoline engines physics applied to the management problem, by the following parameters: air, fuel, torque, engine speed, depollution.

SPARK IGNITION ENGINE MANAGEMENT
Interpreting of the driver’s intentions and taking external requirements into account.
- Taking driving pleasure into account, idle speed.
- How to meet the set torque in SI.
- Air management: translating the instruction into an air quantity and throttle driving, airflow measurements with the pressure/velocity strategy, exhaust gas recirculation EGR. Boost Pressure Management. Valve Control Management.
- Fuel management: fuel supply, starting, evaporative emission system (canister).
- In Diesel engines, managing the injection pressure and the injected quantity, injector driving, injection modes.
- Timing management: torque variations driving by the ignition/knocking advance (ignition computing sequence).

DEPOLLUTION & OBD - SI ENGINES
Standards: presentation of objectives.
- Optimization strategies of the parameters that affect depollution (starting, air-fuel ratio control).
- On Board Diagnostics (OBD): engine control related strategies to meet standards.

DIESEL ENGINE MANAGEMENT
How to meet the set torque. Torque control.
- Air management: translating the instruction into an air quantity, airflow measurements, exhaust gas recirculation EGR. Boost Pressure Management.
- Fuel management: fuel supply, managing the injection pressure and the injected quantity, injector driving, injection modes.
- Timing management: torque variations driving by the ignition/knocking advance (ignition computing sequence).
- Depollution: Diesel particulates filter regeneration, NOx trap, SCR.

This course is also available in French: MOT/ICM. Please contact us for more information.

Reference: MOT/ICM-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com
Level: ADVANCED

Purpose
This course provides a deeper knowledge on the development process of an engine control strategy.

Audience
Engineers and technical staff from design and testing departments or in connection with these departments wishing to understand how power train management is defined, developed and validated. This training is based on an experimental approach by designing a real engine control system.

Learning Objectives
Upon completion of the course, participants will be able to:
- transform a strategy, based on physical phenomena in the engine, into a control law that will be programmed in the computer,
- define, design, simulate, integrate and validate a control strategy in a V cycle development process,
- code and understand the constraints of coding in a real time environment,
- understand and apply the design of experiments,
- know the process to optimize parameters in order to meet the different customers’ needs: cold engine starting, performances, consumption, driving pleasure, noise.

Ways & Means
This training is based on knowledge acquisition through practice. An engine control project is the basis for the learning. The learner is active during this training: he designs, realizes, tests, analyzes and validates himself the engine management system he has developed. Stages of active learning are:
- fully applied training with real world examples on Matlab work station,
- design and calibration of control strategies with Matlab-Simulink,
- engine model and torque structure design with Matlab-Simulink,
- engine management validation with an engine model: MIL,
- manual and automatic coding with Simulink (RTW) and C language,
- software integration in a computer,
- software validation with HIL test,
- validation and calibration on engine test bench.
At the end of the training, participants will own the models, calibration tools, control strategies and a digital computer they have developed.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

FUNCTIONS & STRUCTURE OF AN ENGINE MANAGEMENT SYSTEM
Introduction: why are there electronics in the engines.
General structure of gasoline and Diesel engine management systems.
Components: actuators, sensors, logic controllers.
Electronic system: power supply, webs, optical cables, multiplexing.
Software: structure, input/output processing, strategies, calibrations, evolutions.
Development methods: contributors, key-steps, V cycle, tools.

DEVELOPING A CONTROL LAW
Automatics basic knowledge: tuning the IPD (integral plus derivative) regulator.
Modeling a gasoline engine: system input and output, assessment of the inlet air volume, modeling the intake manifold, assessment of the manifold pressure, throttle gas flow calculation using Barré de Saint-Venant law, ignition advance efficiency, engine dynamics equation and speed calculation.
Control law development practical on Matlab work station: designing an idle speed tuning on a gasoline engine.
Design a torque structure.
Block diagram representation. Establishing the different sub-models: calculation of airflow, of the torque shown, of the speed. Introducing air/fuel ratio and speed measurement noises. Speed IPD regulation.
Exercises to use the created law: actions on the influences and tuning of the IPD regulation parameters.
Observation of the speed signal obtained.
System identification. Real time embedded control. Design of actuators control like body throttle or EGR valve.

VALIDATION OF A CONTROL LAW
Validation steps are performed with Matlab-Simulink, on computer and engine test bench.
Validation steps: What are the reasons? What are the objectives? What kind of technologies and tools are used? MIL - SIL validation: strategy functional validation with an engine modeling.
SIL validation: presentation of the approach, interests of this step, automatic code generation.
HIL validation: presentation of the approach, interests of this step, computer strategy integration after encoding, hardware test on a bench.
Functional validation with an engine, strategy test on engine bench. Comparison between simulation and measurements. Calibration methodology.
Transcription of a control law into a code that can be integrated into the Electronic Control Unit (ECU).
ECU programming and calibration. Automatic coding and manual coding.
Development tools: mock-up and fast prototyping of the engine control strategies.
Fixed point and floating point.

IMPLEMENTING A CONTROL LAW IN A CONTROL UNIT
Transcription of a control law into a code that can be integrated into the Electronic Control Unit (ECU).
ECU programming and calibration. Automatic coding and manual coding.
Development tools: mock-up and fast prototyping of the engine control strategies.
Fixed point and floating point.

DEVELOPMENT & CALIBRATION
The development and calibration work will be illustrated by real examples.
Different performances to be taken into account: basic tuning, performances, driving pleasure, cold engine operability, depollution/standards to meet, DPF regeneration, OBD and diagnostic.
Consideration of dispersions, the surrounding conditions, ageing. Choosing the operating points that represent the cycle. Impact of the different engine tuning parameters.
Example of the advance and EGR calibrations optimization on a constant low load point. Impact of water temperature on the development parameters.
Specific calibrations methodologies. Calibration tools development by the control strategy designer. Calibration scheduling in order to reduce the cost of tuning.
Definition of DoE. Representative operating points. Optimization of calibration. Use of numerical models.

Reference: MOT/LOICOM-E
Only available as an In-House course.
Contact: mt.contact@ifptraining.com
This course is also available in French: MOT/LOICOM. Please contact us for more information.

www.ifptraining.com
**Engine Calibration & Tuning**

**Level:** ADVANCED

**Purpose**

This course provides a better understanding of engine tuning and calibration. It gives an overview of the tuning process to specialists (project, architecture, system design, software development, component development, software integration, functional validation, calibration…).

**Audience**

Engineers and technical staff working on engine control functions, systems or components or closely associated with these activities, in order to improve their knowledge of engine tuning and calibration.

**Learning Objectives**

Upon completion of the course, participants will be able to:
- understand the relationship between engines physical functionalities and customer requirements,
- manage the requirements compromise,
- understand how EMS affects engine performance,
- understand the relationship between design and customer requirements,
- understand EMS tuning process and development,
- know tuning procedures and calibration tools,
- master the theory and the interest of DoE,
- practice develop and DoE,
- understand numerical optimization tools,
- understand the use of numerical models for tuning,
- practice calibration tools and synthesize engine control tuning.

**Ways & Means**

The last two days are based on concrete and practical exercises:
- teaching design of experiment is enhanced by the use of computer tools (Matlab),
- teaching optimization settings is facilitated by the use of industrial computer tools.

**Prerequisites**

No prerequisites for this course.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

**Course Content**

**INTRODUCTION**

Engine management system fundamentals. Tuning process and calibration in a V development cycle. Customer requirements, relationships between engine technical definition and customer requirements.

**FUNDAMENTALS OF ENGINE PERFORMANCE TUNING**

Torque and power concepts. Vehicle acceleration and speed concepts, gear impact.
- Engine constraints and components constraints.
- Engine performance related to injection and fuel control strategies, to air loading, supercharging and air control strategies. Tuning tests and calibrations to ensure engine development performance.

**FUNDAMENTALS OF ENGINE CONSUMPTION - POLLUTION & OBD TUNING**

- Engine emissions related to injection and fuel control strategies. Engine emissions related to air loading and air control strategies. Diagnostics and OBD calibration and development.
- Tuning tests and calibrations to ensure engine emissions development. Measurements, benches, tools and test analysis. Calibration compromises. Inter-compromise performance. Validation plan.
- CO2 regulation, CO2 emissions and tax incentives.
- Engine consumption fundamentals: performance.
- Engine and components constraints.
- Engine consumption calibration related to injection and fuel control strategies, air system and air control strategies, combustion control (phasing injections and ignition).

**FUNDAMENTALS OF ENGINE CONSUMPTION TUNING**

CO2 regulation, CO2 emissions and tax incentives.
- Engine consumption fundamentals: performance.
- Engine and components constraints.
- Engine consumption calibration related to injection and fuel control strategies, air system and air control strategies, combustion control (phasing injections and ignition).

**DESIGN OF EXPERIMENTS**

Customer and cycle driving operating points.
- Design of experiments (DoE) theory.
- Impact of engine operating parameters on tuning.
- Practice of the design of experiments with Matlab.
- Local or global DoE. Calibration methodologies associated with the DoE.

**FUNDAMENTALS OF ENGINE DRIVABILITY**

Definition of the driving pleasure. Drivability objectification.
- Physics fundamentals of powertrain drivability.
- Engine and components constraints.
- Torque structure fundamentals: target, set point and raw torque.
- Drivability strategies: pedal progressivity, anti jerk, dynamic engine speed control, vehicle dynamic control.
- Power train phases of life and related calibration: engine off, on-road driving, highway driving, docking, acceleration, idle speed.

**SYNTHESIS & OPTIMIZATION OF THE ENGINES CALIBRATION**

Digital calibration tools suitable for control strategies.
- Commercial generic digital tools for calibration (type AVL CAMEO).
- Industrialization and integration of calibration methodologies in a development process.
- Minimizing the total number of trials. Creating databases of test data.
- Taking into account the drift and dispersion, environmental measurement conditions in tuning numerical models.
- Exploitation of DoE. Numerical optimization methodologies.
- Autopilot benches. Bench measurements with low dynamics (BFD).
- Practice of a computer optimization and calibration tool.

Reference: MOT/MAPCAL-E

Only available as an In-House course.

Contact: mlcontact@ifptraining.com

1 This course is also available in French: MOT/MAPCAL. Please contact us for more information.
Gasoline Engine Management

**Level:** ADVANCED

**Purpose**

This course provides a deeper knowledge on spark ignition engines: the different functions related to air supply, fuel supply and combustion; the sensors and the actuators related to each of these functions and how to use them.

**Audience**

Engineers and technical staff from design and testing departments wishing to know the main components and functions of the SI engine management.

**Learning Objectives**

Upon completion of the course, participants will be able to:

- have an overview of the gasoline engine control system,
- have the necessary elements to diagnose some simple failure modes,
- talk to specialists to understand and make control strategies evolve.

**Ways & Means**

Interactive training with real life examples.

**Prerequisites**

No prerequisites for this course.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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**Course Content**

**ENGINE MANAGEMENT SYSTEM ARCHITECTURE & TORQUE STRUCTURE**

0.5 d

Logic controller, hardware and Software structures, application engine control architecture. Interpretation of the driver’s intentions. Transients and drivability. Torque supervision, intersystem management. Estimation of FMEP losses (frictions), IMEP LP (pumping): example of data analysis dyno test bench. Basic knowledge on idle speed monitoring.

**AIR SUPPLY FUNCTION**

1 d

Standard air circuit:
- Sensors and actuators: air flow meter, pressure sensor, motor throttle and its control.
- Air supply chain, torque model (or inverted model): combustion equation, Barre de Saint-Venant equation.
- Air supply chain, direct model: loading equation, transients management.
- Dispersions control: closed loop by lambda probe, adaptatives.

Deriving air circuit:
- Turbocharger supercharging, variable timing: sensors and actuators, impact on the control structure. Basic knowledge on the operating safety.

**FUEL INJECTION & IGNITION FUNCTIONS**

1 d

Components and related strategies for the following sub-systems:
- Top dead center and camshaft sensors, acquisition circuits of angular position of crankshaft and camshaft.
- Indirect gasoline injection (MPI) and direct one (GDI), gas injection.
- Canister.
- Upstream and downstream oxygen sensors.
- Ignition: technologies evolutions.
- Knocking: acquisition circuit of the accelerometer signal.

**DIAGNOSTIC, DEPOLLUTION & AGEING OF CATALYST**

0.5 d


This course is also available in French: MOT/CME. Please contact us for more information.

Reference: MOT/CME-E Only available as an In-House course.

Contact: ml.contact@ifptraining.com
Diesel Engine Management

Purpose
This course provides a deeper knowledge on the different functions used in the Diesel engines control, the components used (sensors and actuators), the strategies adopted that take these components and the engine operating physics into account.

Audience
Engineers and technical staff from design and testing departments wishing to know the main components and functions of the Diesel engine management.

Learning Objectives
Upon completion of the course, participants will be able to:

- know the actions performed by the system to realize the set torque (torque structure),
- know how the different sensors and actuators work and when they are used,
- set the control strategies for the turbocharger, the exhaust gas recirculation rate (EGR), the variable swirl system for engines that include it, the injection pressure, the phasing and the injected quantity for each injection performed during an engine cycle,
- use the failures detection modes (diagnostic).

Ways & Means
Interactive training with real life examples.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

TORQUE STRUCTURE
0.5 d
Transmission of the driver’s wished set torque to the wheels by action of the engine control on the air (turbocharger) and fuel (injection system) supply. Pedal mapping. Working with a driven engine or with a cruise control. Interaction of the other systems of vehicle stability (AESP, ASR).

AIR SUPPLY FUNCTION
1 d
Airflow regulation by the EGR valve and of the intake collector pressure by the turbocharger actuator position. Interaction between the EGR regulation and the turbocharger regulation. Advantage of an oxygen probe in the EGR regulation. Cycle adjustment in dynamics to optimize pollutant emissions. Operating the variable swirl shutters, the EGR cooler by-pass.

FUEL INJECTION FUNCTION
1 d
Pressure oscillations created during injection, influence on the injected flow rates during multi-injections. Correction by a hydraulic behavior simulation model. Choosing the drive ratio of the high pressure pump, influence of the rail volume and of the HP pipe lengths on the injected flow rate. Rail pressure regulation on high or low pressure. Engine speed regulation, regulation by function, idle speed regulation, anti-surges.

FAILURES DIAGNOSTICS
0.5 d
Diagnostics of rail pressure loop differences, of minimum pressure monitoring, sensor signal plausibility. Supercharging pressure diagnostic. Depollution system diagnostics (OBD).

Reference: MOT/CMD-E Only available as an In-House course.

This course is also available in French: MOT/CMD. Please contact us for more information.

Contact: ml.contact@ifptraining.com
# Introduction to Engine Management: Practical Approach by Modeling & Simulation

**Level:** ADVANCED  
**Purpose**  
This course provides a deeper knowledge on the strategies used to manage the engine operation in order to improve performances.

**Audience**  
Engineers and technical staff from design and testing departments wishing to discover the engine management in a practical way and desiring a comprehensive and practical understanding of engine control.

**Learning Objectives**  
Upon completion of the course, participants will be able to:  
- determine and to carry out SI and Diesel engines set torque, by air, timing and fuel management,  
- know de-pollution and OBD strategies necessary to meet the standards,  
- understand the relationship between engine physics and control,  
- know control basics,  
- understand the relationship between EMS design and customer requirements,  
- understand engine management system process development,  
- identify the components necessary to control the engine and its requirements as well as to describe their operation,  
- design and develop engine control strategies,  
- validate and calibrate engine control strategies.

**Ways & Means**  
This training provides an overview of engine management systems. It is based on concrete examples and a pragmatic approach by modeling and simulation. A control project underlies learning. Students are active throughout the training: they develop, realize, test and validate themselves the control software they have developed.  
The steps in this active learning are:  
- Design, build and calibration of control strategies in Matlab-Simulink,  
- Engine model development for torque structure design with Matlab-Simulink,  
- Strategies validation with an engine model (MIL) with Matlab-Simulink.

**Prerequisites**  
This training requires a basic knowledge related to the components of engine control such as the knowledge offered in Spark Ignition Engines and Diesel Engines.  
It is of interest to initially follow MOT1-E, MOT/MOT2-E and MOT/MOT3-E.

**Expertise & Coordination**  
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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**Course Content**

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Management Introduction &amp; Discovery by Practice</td>
<td>3.5 d</td>
</tr>
</tbody>
</table>
| Stakes, definitions, architectures, sensors, actuators, ECU, control strategies.  
  Automatisms: PID regulators (principle, tuning, gasoline idle speed and Diesel EGR control), new tuning methods and prospects.  
  Diesel and gasoline engines physics applied to the management problem, by the following parameters: air, fuel, torque, speed, depollution.  
  Control law “hands design”. All introductory concepts are reworked with the example of a spark ignition engine: design and implementation of a torque structure, design and implementation of an idle speed control strategy. | 9 days   |

| SPARK IGNITION ENGINE TORQUE & EMISSIONS CONTROL                           | 1.75 d   |
| Interpreting of the driver’s intentions and taking external requirements into account.  
  Taking driving pleasure into account, idle speed.  
  How to meet the set torque.  
  Air management: translating the instruction into an air quantity and in throttle driving, airflow measurements with the pressure/velocity strategy, exhaust gas recirculation EGR.  
  Fuel management: fuel supply, starting, evaporative emission system (canister).  
  Managing the injection pressure and the injected quantity, injector driving, injection modes.  
  Timing management: torque variations driving by the ignition/knocking advance (ignition computing sequence).  
  Operation of pollutant strategies to control engine out and after-treatment. |         |

| DIESEL ENGINE TORQUE & EMISSIONS CONTROL                                   | 1.75 d   |
| How to meet the set torque. Diesel torque structure. Torque control by injection control.  
  Air management: translating the torque instruction into an air quantity, supercharching control.  
  Fuel management: fuel supply, starting, managing the injection pressure and the injected quantity, injector driving, injection modes, control of the injection patterns.  
  Injections corrections strategies.  
  Operation of pollutant strategies to control engine out and after-treatment.  
  Pollutants and air diesel chain: controlling the amount of air, amount of fresh air and EGR rate.  
  After-treatment control systems: oxidation catalyst, DPF, SCR and NOx trap. |         |

| ENGINE CROSS CONTROL                                                       | 2 d      |
| Engine synchronization: crankshaft and cam timing. Strategies, operating technologies and components.  
  Powertrain supervision: Interpreting the driver will, choice of the powertrain operating point, intersystem arbitration.  

---

Reference: MOT/CMCS-E  
This course is also available in French: MOT/CMCS. Please contact us for more information.

Contact: ml.contact@ifptraining.com

Only available as an In-House course.

www.ifptraining.com 51
Engine Management Training

Level: ADVANCED

Purpose
This course provides engineers with a deeper knowledge on the engine operating physics and the engine electronic control in order to take part in the development of control and calibration strategies on a Dyno test bench and on a vehicle.

Audience
Engineers and technical staff from automotive industry who want to improve their knowledge of powertrain electronic management.

Learning Objectives
Upon completion of the course, participants will be able to:
- know the parameters used to characterize and control performances, efficiency, combustion, emissions,
- know the combustion mechanisms and how the exhaust gas after-treatment systems work,
- know the architecture and the functions of the engine control systems, the sensors and the actuators,
- have some basic practical knowledge on applied automatics to engine control,
- describe the advantages and the make-up of a torque structure,
- tune up the control strategies of gasoline and Diesel engines, possibly associated to an automatic transmission,
- implement of the diagnostic functions, both from regulatory and operating safety standpoints,
- know how to build a control law,
- do the tuning and calibration process on an engine.

Ways & Means
- Fully detailed training with applied exercises.
- Basic simulation may be used.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ENGINE OPERATING & TECHNOLOGY 13 d
Thermodynamic cycles, engine general architecture, technology of the different components.
Geometric parameters, effective and shown performances parameters, efficiency, emissions, air loading parameters.
Engine mechanics: stress transmission, rotating and alternative masses balancing, acylisms, vibrations.
Combustion in spark ignition engines and in compression ignition engines: pollutants formation, normal and abnormal combustion.
Control parameters: airflow, fuel flow, intake temperature and pressure, residual burnt gas, ignition or injection advance. How changing these parameters (motorized throttle intake exhaust gas recirculation, gasoline and Diesel fuel injection systems, variable timing, turbocharging).
Fuels: characteristics, influence on engine operation.
Exhaust gas after-treatment systems: catalysts, filters, traps; trap bleeding and filter regeneration systems; control strategies of these systems.

ENGINE MANAGEMENT 17 d
Hardware:
- Electronic control system architecture, data exchanges, development process.
- Technical definition, properties and use of sensors (flow rate, speed, position, pressure, temperature, oxygen probe) and of actuators (injectors, motorized throttle, EGR valves, ignition).
Software:
- Torque structure. Slow and fast control. Development of a control law on the example of idle speed regulation on a gasoline engine.
Gasoline engines control strategy: architecture, synchronization, air loop, fuel injection, air/fuel ratio regulation, ignition advance, anti-knock correction, canister bleeding, catalyst actuation.
Diesel engines control strategy: rail pressure, injected flow, multi-injections, correction of dispersions, unbalances between injectors, drifts, supercharging, EGR, after-treatment.
Control in the case of automatic transmission: shift laws, interference with torque structure.
Diagnostic: EOBD regulation, operation safety; loop difference.
Statistical analysis, failures, torque structure monitoring, degraded modes. Roles and development process.

Reference: MOT/CTRLM-E Only available as an In-House course.
This course is also available in French MOT/CTRLM. Please contact us for more information.

Contact: ml.contact@ifptraining.com
Lubrication

- **Chemical Physics of Lubricants & Lubrication Theory**
  - Introduction to Lubrication ................................................................. p. 54
  - Lubrication & Lubricants ..................................................................... p. 55

- **Automotive & Industrial Engines Lubrication**
  - Car Engines Lubrication ..................................................................... p. 56
  - Industrial Engines Lubrication & Technology .................................... p. 57
  - Lubrication & Technology of Automotive Transmissions ............... p. 58
  - Lubricating Greases Automotive & Industrial Applications .......... p. 59
  - Introduction to Automotive Lubricants ............................................. p. 60

- **Industrial Lubrication**
  - Lubrication & Technology of Industrial Equipment ....................... p. 61
  - Introductory Course to Automotive & Industrial Lubricants .......... p. 63
  - Lubricants .......................................................................................... p. 64
Introduction to Lubrication

Level: DISCOVERY

Purpose
This course provides a deeper knowledge on lubricants and their mode of action in internal combustion engines and other mechanical organs, their rheological behavior of lubricants in internal combustion engines, as well as the different lubricating regimes and their mechanisms of generation according to the functioning parameters.

Audience
Engineers and technical staff of the automotive and mechanical industry confronted with lubrication problems and desiring to acquire basic knowledge on the principles of lubrication and on lubricants.

Learning Objectives
Upon completion of the training, participants will know:
► the different lubrication types (tribology),
► the different wear types and the appearance of such wears,
► the lubricants flow properties (rheology),
► all the properties required for engine lubricants,
► the lubricants classification principles and specifications.

They will be able to understand the possible origins of a lubrication problem and the consequences of the choice of a lubricant and to ask the good questions to the field specialists.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Reference: LUB/INTLUB-E
Only available as an In-House course.

Course Content

CLASSIFICATIONS & SPECIFICATIONS OF LUBRICANTS 3 days
Lubricants rheology: the different types of flow behavior (Newtonian, non-Newtonian, Bingham fluid, Maxwell fluid, thixotropic), variation of viscosity with temperature, pressure, deformation, measuring methods of rheological properties, viscosity classifications of automotive and industrial lubricants.

Service specifications of engine lubricants: API, ACEA, ILSAC, engine testing for performance evaluation.

ELEMENTS OF TRIBOLOGY 3 days
Friction laws.
Study of the different lubricating regimes (hydrodynamic, hydrostatic, elastohydrodynamic, boundary, mixed, squeeze film) and their mechanism of generation. Strubeck curve. Sommerfeld number.

Study of the different forms of wear, their mechanism, the way to fight against them (abrasive, corrosive, fatigue, contact corrosion, cavitation wear).

Relationship between wear and tribology parameters.

FUNCTIONAL PROPERTIES OF LUBRICANTS & COMPOSITION 3 days
Functional properties of lubricants according to the equipment lubricated. Effect of the properties and the utilization of the equipment.

Lubricants composition:
► Base stocks mineral and synthetic, composition, compared performances.
► Additives: the different types, their roles and their mode of action (detergents, dispersants, antioxidants, viscosity modifiers, pour point depressants, extreme-pressure, anti-wear, friction modifiers, rust and corrosion inhibitors, antifoaming agents).

Notions on the formulation of lubricants.

This course is also available in French: LUB/INTLUB. Please contact us for more information.

Contact: ml.contact@ifptraining.com
# Chemical Physics of Lubricants & Lubrication Theory

## Course Content

### Lubricated Materials & Mechanisms

- General description of the main mechanical organs (journal and antifriction bearings, gears) and their integration in the various industrial and automotive equipment.
- Functional properties of lubricants.

### Classifications & Specifications of Lubricants

- Lubricants rheology: the different types of flow behavior (Newtonian, non Newtonian, Bingham fluid, Maxwell fluid, thixotropic), variation of viscosity with temperature, pressure, deformation, measuring methods of the rheological properties, viscosity classifications of automotive and industrial lubricants.
- Service specifications of engine lubricants: API, ACEA, ILSAC.

### Elements of Tribology

- Friction laws.
- Study of the different lubricating regimes (hydrodynamic, hydrostatic, elastohydrodynamic, boundary, mixed, squeeze film) and their mechanism of generation. Stribeck curve. Sommerfeld number.
- Study of the different forms of wear, their mechanism, the way to fight against them (abrasive, corrosive, fatigue, contact corrosion, cavitation wear).
- Relationship between wear and tribology parameters.

### Composition of Lubricants

- Mineral base oils: ATIEL groups, requested properties following the type of lubricant, chemical composition, succinct review of the different refining operations, composition evaluation methods.
- Synthetic base oils: ATIEL groups, the different types of synthetic base stocks, synthesis of the products, application areas and comparative properties with the mineral base stocks.
- Vehetial oils: modes of obtaining, properties, modifications, uses.
- Lubricants additives: chemical structure, properties and modes of action (detergents, dispersing agents, antioxidants, rust and corrosion inhibitors, viscosity modifiers, pour point depressants, extreme pressure and anti-wear additives, anti-foaming agents).
- Solid lubricants: the different types, characteristics and properties, main uses.

### Evaluation of the Properties

- Physico-chemical testing methods: thermal and oxidation stability, thermal properties (flash points, ash, carbon residues), rust and corrosion protection, surface properties (foaming, air release, water shedding, particulate contamination evaluation and filterability, compatibility with elastomeric materials).
- Mechanical testing methods: notions on engine testing, tests on mechanical organs (bearing tests, gear tests, hydraulic pump tests), simulation machines testing and laboratory tribometers (4-balls, FALEX, TIMKEN, CAMERON PLINT, SRV ...).
- Analytical methods of the composition: elemental and spectrometric analysis.

### Principle of Formulation of Lubricants & Examples

- Formulation of industrial lubricants.
- Formulation of engine lubricants.

### Hygiene - Toxicity - Environment

- Elements on toxicity, hygiene, labeling.
- Ecological label of lubricants.

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**Reference:** LUB/LUBLUB-E  
Only available as an In-House course.

**Contact:** mt.contact@ifptraining.com

This course is also available in French: LUB/LUBLUB. Please contact us for more information.

www.ifptraining.com
Car Engines Lubrication

Course Content

3 days

ENGINE OILS CLASSIFICATIONS & SPECIFICATIONS 0.75 d
Evolution of the engine oils market (passenger cars and industrial vehicles). SAE viscosity classification; API, ILSAC, ACEA, global classifications. ACEA, API and global service specifications. Engine testing for lubricants performance evaluation: wear protection, deposits formation tendency, oxidation stability (thickening), foaming, aeration…

LUBRICATION CIRCUIT 0.5 d

LUBRICATION OF THE PISTON - RING - LINER AREA 0.5 d

LUBRICATION OF THE SHAFT LINE & TIMING 0.5 d
Lubrication of bearings, lubrication regimes, analysis of the failure modes of bearings, rocker arms, tappets, hydraulic tappets, (abrasive, adhesive, fatigue, cavitation…, wear). Essential properties of the lubricant and influence on fuel economy.

ATIEL SYSTEM OF ENGINE OIL DEVELOPMENT & RESULTS OF THE DEVELOPMENT 0.5 d

ANALYSIS OF ENGINE OILS IN SERVICE 0.25 d
Evolution of the characteristics of the lubricant with its ageing (viscosity, elements content…). Characteristics bond to contamination and engine wear). Analytical means and interpretation of the results.

Ways & Means

- Interactive exercises with the teacher to determine the lubricant to use according to the type of vehicle, the climate and operating conditions.
- Interactive exercises of questions-answers between the participants using sets of play cards to synthesize the essential points of the lectures.

Prerequisites

To maximize the benefits of this training, it is strongly recommended to initially follow the training entitled “Introduction to engines”.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Reference: LUB/LUBMA-E Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: LUB/LUBMA. Please contact us for more information.
Industrial Engines Lubrication & Technology

Level: ADVANCED

Purpose
This course provides a technical information on the technology of the industrial engines, the industrial road vehicles, agricultural vehicles and public works vehicles, railway traction, nautical propulsion, stationary engines (gas, Diesel engines, cogeneration) and on the lubricants used.

Audience
Engineers and technical staff working in development, technical assistance and sales of lubricants for industrial engines; engineers and technical staff from industrial engines manufacturers. Well adapted to training abroad.

Learning Objectives
Upon completion of the course, participants will be able to:

- master the industrial engines structure and operation,
- know the lubricant functions and their requirements depending on the engines,
- understand the meaning of the specifications,
- be able to interpret the analysis results of the in-service oils.

Ways & Means
Interactive talk with an industry expert using real world examples.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCHITECTURE OF HEAVY TRUCKS &amp; INDUSTRIAL ENGINES</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Differences and specificities compared with light cars: chassis frames, cylinder heads, crankshaft, conrods, piston pins, pistons, rings, liners, valves and control.</td>
<td></td>
</tr>
<tr>
<td>DIESEL FUELS</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Main Diesel fuels (Diesel fuel, FOD, heavy fuels, EMHV, GTL, BTL). Impact of the fuel type on the lubricant.</td>
<td></td>
</tr>
<tr>
<td>LUBRATION CIRCUITS</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Principle, role and description depending on the different engine types.</td>
<td></td>
</tr>
<tr>
<td>DIESEL ENGINES LUBRICANTS</td>
<td>1 d</td>
</tr>
<tr>
<td>Classifications and specifications. Brief presentation on lubricants composition, design (ATIEL codes) and testing (physico-chemical and mechanical) rules.</td>
<td></td>
</tr>
<tr>
<td>FOLLOW UP OF THE IN-SERVICE ENGINE OILS</td>
<td>0.25 d</td>
</tr>
<tr>
<td>Objectives of the follow up, sampling, analytic techniques used (the results interpretation will be handled separately for each type of application).</td>
<td></td>
</tr>
<tr>
<td>LUBRATION OF HEAVY TRUCKS, AGRICULTURAL, PUBLIC WORKS VEHICLES DIESEL ENGINES</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Presentation of the materials and of the manufacturers’ recommendations. Specific problems according to the use. Maintenance and follow up of in-service lubricants. Types of problems found and solutions.</td>
<td></td>
</tr>
<tr>
<td>LUBRATION OF RAILWAY TRACTION DIESEL ENGINES</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Different types of materials and different types of lubricants used. Maintenance and follow up of in-service lubricants. Types of problems found and solutions.</td>
<td></td>
</tr>
<tr>
<td>LUBRATION OF NAUTICAL DIESEL ENGINES (2S &amp; 4S)</td>
<td>0.5 d</td>
</tr>
<tr>
<td>Fuels used in the navy. Choosing a lubricant depending on the engine type and the fuel type. Maintenance and follow up of in-service lubricants. Types of problems met and solutions.</td>
<td></td>
</tr>
<tr>
<td>LUBRATION OF GAS &amp; COGENERATION ENGINES</td>
<td>0.75 d</td>
</tr>
<tr>
<td>Gas engines: reasons for their development, lubrication requirements. Gas engine lubricants: products specificities and characteristics, manufacturers’ requirements, follow up of in-service lubricants, real case studies.</td>
<td></td>
</tr>
</tbody>
</table>

Reference: LUB/LUBMIE-E Only available as an In-House course.

Contact: ml.contact@ifptraining.com

www.ifptraining.com
# Lubrication & Technology of Automotive Transmissions

**Level:** ADVANCED

**Purpose**

This course provides a technical overview on all automotive mechanical transmissions components and their operation. It gives information on all types of lubricants used and their classifications and specifications according to the type of transmission. The course also presents information on the specificities of some manufacturers concerning the lubricants to be used.

**Audience**

Engineers and technical staff involved in the recommendations, sales and technical follow ups of automotive transmission lubricants in different areas of activities and to engineers and technicians of the automotive industry.

**Learning Objectives**

Upon completion of the course, participants will be able to:

- perform a technical refresher on the different types of gears used in automotive transmissions,
- perform a technical refresher on gear lubrication,
- know the different classifications and specifications of transmission fluids,
- understand elements on the architecture and the operation of the different types of transmissions depending on the type of vehicle (passenger, industrial, off-road).

**Ways & Means**

Interactive exercises of questions-answers between the participants using sets of play cards to synthetize the essential points of the lectures.

**Prerequisites**

No prerequisites for this course.

**Expertise & Coordination**

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

## Course Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td><strong>INTRODUCTION</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td>Need for a transmission in an automotive vehicle. The different solutions for propulsion. Technological refresher on gears and their lubrication. Succinct notions on the calculation of a gear box, the aperture, staging. Construction of a gear box.</td>
<td></td>
</tr>
<tr>
<td><strong>CLASSIFICATIONS &amp; SPECIFICATIONS</strong></td>
<td>0.25 d</td>
</tr>
<tr>
<td><strong>PASSENGER CARS GEAR BOXES</strong></td>
<td>1 d</td>
</tr>
<tr>
<td><strong>AXLES &amp; DIFFERENTIALS</strong></td>
<td>0.25 d</td>
</tr>
<tr>
<td>Differentials: refresher on epicycloidal trains and on the functioning of the Pecqueur train. Limits and technical solutions. Final reductions: different types (bevel, hypoid, worm). Respective advantages and drawbacks. Lubrication: requirements following the type.</td>
<td></td>
</tr>
<tr>
<td><strong>GEAR BOXES OF INDUSTRIAL VEHICLES</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td>Mechanical gear boxes: main differences with passenger cars (relay boxes, speed reducers…). Lubrication requirements. Specificities of manufacturers. Automatic gear boxes: specificities of the application versus passenger cars.</td>
<td></td>
</tr>
<tr>
<td><strong>FARM &amp; PUBLIC WORKS EQUIPMENT (Off Road)</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td>Specificities of the application. Some particular solutions: farming tractors, public works machines, forestry machines…</td>
<td></td>
</tr>
</tbody>
</table>

Reference: LUB/LUBTA-E  
Only available as an In-House course.  
This course is also available in French: LUB/LUBTA. Please contact us for more information.

Contact: ml.contact@ifptraining.com
Level: ADVANCED

Purpose

This course provides an overview of the antifriction bearings technologies in automotive and industrial transmissions. To provide basic knowledge on greases: description, composition, production, testing methods, lubrication mechanism, classifications and specifications and various properties. To study more particularly the lubrication of bearings with grease, the criteria for the choice of a grease according to the operating conditions. To learn how to identify the failure causes of bearings. To study the lubrication of automotive and industrial transmissions with grease.

Audience

Engineers and technical staff concerned by the development, manufacture, recommendations and use of greases in automotive and industrial organs susceptible to be lubricated with this type of lubricant. Engineers and technical staff of the automotive and mechanical industry.

Learning Objectives

Upon completion of the course, participants will be able to:

▸ understand the main points on grease: structure, properties, production modes, testing methods and performance characterization, different types of greases and criteria for the choice according to the applications,

▸ know the applications of grease other than bearings (gears, automotive and industrial transmissions, couplings),

▸ recommend a bearing grease according to the operating conditions and to calculate the lubrication intervals and the lifetime,

▸ recognize the bearing failures and identify the origins.

Ways & Means

▸ Interactive exercises with the teacher for the determination of a bearing grease, the lubrication intervals, the lifetime calculation of bearings according to the operating conditions.

▸ Interactive exercises of questions-answers between the participants using sets of play cards to synthetize the essential points of the lectures.

Prerequisites

No prerequisites for this course.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Reference: LUB/LUBGR-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: LUB/LUBGR. Please contact us for more information.
Introduction to Automotive Lubricants

Course Content

<table>
<thead>
<tr>
<th>3 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE AUTOMOTIVE LUBRICANTS MARKET DISTRIBUTION &amp; SALES CHANNELS</td>
</tr>
<tr>
<td>CONSTITUTION OF AN AUTOMOTIVE VEHICLE - TECHNOLOGY OF THE LUBRicated ORGANS</td>
</tr>
<tr>
<td>Engine: description, running cycles, critical areas of lubrication, pollution, lubricating circuit. Gear boxes: manual and automatic gear boxes. Succinct description of functioning. Final reduction final: different types and succinct description of functioning.</td>
</tr>
<tr>
<td>STUDY OF LUBRICATION &amp; LUBRICANTS</td>
</tr>
<tr>
<td>Friction laws, different lubrication regimes, wear, flow properties. The different types of lubricants: liquid, solid, pasty. Functional properties of lubricants. Constitution of lubricants: base oils and additives. Main characteristics of lubricants.</td>
</tr>
<tr>
<td>ENGINE LUBRICATION</td>
</tr>
<tr>
<td>SAE, API, ILSAC, ACEA classification and of system specifications. Functional properties of engine oils. Present themes: oil consumption, draining intervals, compatibility with after-treatment systems.</td>
</tr>
<tr>
<td>TRANSMISSIONS LUBRICATION</td>
</tr>
<tr>
<td>SAE, API classifications systems, manufacturers. Functional properties of manual and automatic transmission gear boxes.</td>
</tr>
<tr>
<td>MISCELLANEOUS FLUIDS &amp; GREASES</td>
</tr>
<tr>
<td>Greases for bearings and transmissions. Oil shock absorbers. Brake fluids. Cooling liquids and antifreeze.</td>
</tr>
</tbody>
</table>
Lubrication & Technology of Industrial Equipment

Level: ADVANCED

Purpose
This course provides a deeper knowledge on the material and equipment to the non-mechanical people for a better understanding of the role of the lubricant. It presents the essential properties of lubricants depending on the equipment and their operating conditions.

Audience
Engineers and technical staff involved in the recommendation and the use of lubricants in industrial equipment, their maintenance and the identification of the origin of the equipment failures.

Learning Objectives
Upon completion of the course, participants will be able to:
- describe the different mechanical organs and machines used in the industry,
- explain the role and the importance of the standardization in the field of lubrication and lubricants,
- explain the mode of action of the lubricants and the properties required for a given application,
- recommend a lubricant according the equipment and its operating conditions,
- detect the origin of the equipment failures,
- select a lubricant for a given equipment,
- analyze lubricants in use.

Ways & Means
- Interactive exercises with the teacher will be conducted to determine the lubricant to be used based on the technical data of the equipment and its operating conditions.
- Interactive exercises of questions-answers between the participants using sets of play cards to synthesize the essential points of the lectures.

Prerequisites
In order to maximize the benefits of this training course, it is strongly recommended to initially follow the training course entitled “Lubrication & Lubricants”.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

**GENERALITIES ON EQUIPMENT & REFRESHER ON LUBRICANT**

- Description of the different basic mechanical organs; functional properties of lubricants; ISO standards of classification and specifications; physico-chemical characterization of products; chemical composition of lubricants.

**LUBRICATION OF HYDRAULIC CIRCUITS**


**LUBRICATION OF MACHINE TOOLS**

- Description of the different types of slide-ways and of their different lubrication requirements. Functional properties, classifications and specifications. Lubrication plans of machine tools. Possible problems in service.

**LUBRICATION OF INDUSTRIAL GEARS**


**LUBRICATION OF JOURNAL & ANTIFRICTION BEARINGS**


**LUBRICATION OF TURBINES & DYNAMIC COMPRESSORS**

- Description and functioning of steam, gas, combined cycle and hydraulic turbines, of axial and radial compressors. Lubrication circuits. Functional properties, classifications and specifications according to type of equipment. Follow-up in service and possible problems.

**LUBRICATION OF VOLUMETRIC & REFRIGERATING COMPRESSORS**

- Description and functioning of reciprocating, rotary and refrigerating compressors. Refrigerating fluids (CFC, HCFC, HFC); replacement of CFC and HCFC. Functional properties, classifications and specifications, according to the type of compressed gas (air, industrial gas, refrigerating fluids). Exercise of selection of a refrigerating oil for a refrigerating compressor. Possible problems in service.

**FOLLOW UP OF LUBRICANTS IN SERVICE**

- Interest. The different types of maintenance (preventive, conditional, healing). Ageing of the components, follow up of lubricants and machines. Management of analysis and analytical methods used. Analysis menus following the lubricants, periodicity of sampling. Interpretation of the analysis results.

Reference: LUB/LUBEI-E  
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: LUB/LUBEI. Please contact us for more information.

Reference: LUB/LUBEI-E  
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

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Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: LUB/LUBEI. Please contact us for more information.

Reference: LUB/LUBEI-E  
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

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This course is also available in French: LUB/LUBEI. Please contact us for more information.
# Lubrication of Metal Working Operations & Machine Tools

## Level: ADVANCED

### Purpose

This course provides a better knowledge on metal removal operation and plastic deformation to the non-specialized people for a better understanding of the role of the lubricant. It gives information on the different types of products (functional properties, chemical composition, characterization methods) and presents an overview of the problems raised by the products in use, from their introduction in use to their withdrawal, including the hygiene, toxicity and environmental aspects.

### Audience

Engineers and technical staff involved in the development, recommendations, use, maintenance and follow up of the fluids (essentially cutting, rolling, thermal treatment) and the lubrication of machine tools, as well as the solving of operating issues.

### Learning Objectives

Upon completion of the course, participants will be able to:
- detail the different machines used for metal removal and rolling,
- describe the different metal working operations,
- describe the different types of fluids for metal working and thermal treatment,
- give the information needed to introduce the fluids in use, their follow-up and their withdrawal,
- solve the possible in-service issues,
- give the necessary information of the toxicity, hygiene and environmental aspects.

### Ways & Means

- Interactive exercises with the teacher to determine the lubricant to use depending on the type of organ and the operating conditions.
- Interactive exercises of questions-answers between the participants using sets of play cards to synthetize the essential points of the lectures.

### Prerequisites

No prerequisites for this course.

### Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

## Course Content

### MACHINE TOOLS & ROLLING MILLS

**Description of the different types of machine tools and rolling mills. Lubrication plans of the various equipment.**

**0.5 d**

### MAIN OPERATIONS OF METAL WORKING

**Description, principle and mechanism of the metal removal operations (cutting, spark erosion). Machinability of materials, wear modes of cutting tools. Description and mechanism of the metal forming operations (rolling, deep drawing, forging, extrusion, wire drawing). Description and mechanism of thermal treatment operations (quenching, annealing, tempering).**

**0.5 d**

### FLUIDS FOR METAL MACHINING & THERMAL TREATMENT

**General classification and specifications:**
- Metal working: ISO 6743-7 classification and ISO 12927 specification.
- Thermal treatment: ISO 6743-14 classification.

**Neat oils:**
- Chemical composition (base stocks and additives) - Characterization of the products and evaluation performance. Composition performance relationship.

**Water mixed fluids:**
- Chemical composition (base stocks and additives) - Characterization of the products and evaluation performance. Composition performance relationship.
- Biology of water based fluids (bacterial phenomena, fluids degradation, prevention of bacterial degradation.
- Quenching and tempering products:

**1.25 d**

### FLUIDS IN SERVICE

**Ageing of the products and follow up in service (mechanism of the ageing, analytical methods for follow up, interpreting the results).**
- Possible problems in service: pollution by foreign oils (hydraulic, slide-ways, rust preventives); miscellaneous pollutions (metal, calamine); treatments of products in service (foam suppressors, biocides…). Withdrawal of the products: methods and channels.

**0.5 d**

### HYGIENE - TOXICITY - ENVIRONMENT

**Toxicity and product labeling.**
- Products susceptible to raise problems or under debate: boric acid, alkanol amines, C10-C13 chlorinated paraffins, formaldehyde and derivatives - Corresponding labels and associated phrases of risks.
- Aerosols of neat and water based fluids.
- Toxicity of emulsion in service.

**0.25 d**

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**Reference:** LUB/LUBTMX-E

*Only available as an In-House course.*

**Contact:** ml.contact@ifptraining.com

*This course is also available in French: LUB/LUBTMX. Please contact us for more information.*
Introductory Course to Automotive & Industrial Lubricants

Level: DISCOVERY

Purpose

This course provides a deeper knowledge on the equipment being lubricated: internal combustion engines, automotive transmissions, industrial equipment (hydraulic pumps, gears, compressors, turbines, antifriction bearings, machine tools).

It presents the key elements needed to understand how the lubricants operate in the various equipment, as well as their functional properties for each type of equipment, their classifications and specifications.

Audience

Engineers and technical staff, beginners in the field of lubricants, wishing to get an overview on automotive and industrial lubricants.

Learning Objectives

Upon completion of the course, participants will be able to:

► master the technology of the automotive and industrial equipment currently used,
► understand the various lubricants applied in the equipment in terms of functional properties, classifications and specifications,
► recommend a lubricant for a given application.

Ways & Means

Interactive exercises of questions-answers between the participants using sets of play cards to synthetize the essential points of the lectures.

Prerequisites

To maximize the benefit of this training course, it is strongly recommended to initially follow the training course entitled “Lubrication & Lubricants”.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

<table>
<thead>
<tr>
<th>5 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENGINE LUBRICANTS</td>
</tr>
<tr>
<td>Elements on engine technology in relation with lubricants properties. Passenger car engine oils: role, properties, classifications and specifications (API, ACEA, ILSAC). Industrial vehicle lubricants: role, properties, classifications and specifications (API, ACEA, ILSAC).</td>
</tr>
</tbody>
</table>

| AUTOMOTIVE TRANSMISSION LUBRICANTS | 0.75 d |
| Elements on automotive transmission technologies. Automotive transmission oils (manual and automatic): role, properties, classifications and specifications. |

| HYDRAULIC LUBRICANTS | 0.5 d |

| INDUSTRIAL GEAR LUBRICANTS | 0.5 d |

| COMPRESSOR LUBRICANTS | 0.5 d |

| TURBINE LUBRICANTS | 0.5 d |
| Elements on the different types of turbines (steam, gas, hydraulic). Lubrication requirements. Turbine lubricants functional properties, classifications and specifications. Recommending a lubricant. Possible problems in service. |

| PLAIN & ANTIFRICTION BEARING LUBRICANTS | 0.5 d |
| Elements on plain and anti-friction bearings technologies. Lubrication requirements according to the type. Bearing oils and greases description, requirements, classifications and specifications. Recommending a bearing oil or grease. Bearing failures: identification, origin and solutions. |

| MACHINE-TOOLS LUBRICANTS | 0.5 d |
| Description and role of machine tools - Elements on the different constituting organs. Lubrication requirements, putting more emphasis on slide-ways lubrication. Lubrication scheduling. Possible problems in service. |

Reference: LUB/INILAI-E Only available as an In-House course. Contact: ml.contact@ifptraining.com
Lubricants
Advanced Courses

Level: FOUNDATION

Purpose
The course “Automotive and industrial lubricants” being an introduction course intended mainly for beginners in the lubrication and the lubricants areas, other advanced courses may be organized, on request and for a minimum number of attendees, covering all the lubricants technical areas.
The main parts of the program of the course are given, but the contents may be adapted to suit particular requirements. It provides participants with extended information on the equipment technology to be lubricated and on the relationship with the lubrication requirements, as well as on the lubricants properties.

Audience
Engineers and technical staff beginning working in development, technical assistance, manufacturing or sales of lubricants.
Mandatory prerequisite: “Lubrication and lubricants” and “Automotive and industrial lubricants”.

Learning Objectives
Upon completion of the course, participants will be able to:
► understand the fundamentals about the equipment technology related to lubrication,
► understand the lubricants operating requirements,
► know how to recommend a lubricant and how to identify the causes of in-service issues and how to solve them.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ENGINE LUBRICATION
5 d
Engine technology.
Engine lubricants development and testing.
Engine lubrication and wear.
Monitoring of engine oils in use.
Engine lubricants trends.

LUBRICATING GREASES: AUTOMOTIVE & INDUSTRIAL APPLICATIONS
2.5 d
Description, properties, manufacturing and control.
Mechanical and physico-chemical testing.
Automotive applications (hub unit, constant velocity joints).
Industrial applications (bearings, gears, universal joints, couplings).
Bearings failures, identification and causes.

METAL WORKING LUBRICATION - HEAT TREATMENT OILS
2.5 d
Machine-tool technology, lubrication and lubricant. Lubrication scheduling.
Metal working principles: cutting, distortion.
Study of cutting oils, plain and emulsifiable ones: composition, properties, applications, in-service problems, disposal.
Study of rolling oils, plain and emulsifiable ones: composition, properties, applications, in-service problems, disposal.
Heat treatment: principle, techniques, fluids.
Temporary protection against corrosion fluids.

Reference: LUB/LUBADV-E  Only available as an In-House course.

Contact: ml.contact@ifptraining.com
Management of a Powertrain Project with Chinese Partner

<table>
<thead>
<tr>
<th>Level: DISCOVERY</th>
</tr>
</thead>
</table>

**Purpose**
This course provides designers or project managers with keys to manage new situations following their involvement in multi-company multicultural collaboration projects.

**Audience**
Engineers or powertrain project leaders who have to work in China with Chinese companies.

**Learning Objectives**
Upon completion of the course, participants will be able to:
- understand the powertrain sector in China,
- know the Chinese development process,
- identify development opportunities,
- better understand Chinese culture.

**Ways & Means**
Training presented by a Chinese-French company manager in a play approach.

**Prerequisites**
No prerequisites for this course.

**Expertise & Coordination**
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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### AUTOMOTIVE MARKET IN CHINA
1 d

- China’s auto market.
- Major players: foreign and Chinese manufacturers.
- The ambitions of Chinese manufacturers.
- French manufacturers in China: PSA and Renault.
- French OEMs in China: Valeo, Faurecia…
- Major issues of powertrain in China.
- Existing and mature technologies.
- Regulatory changes.
- Technical developments of powertrains.
- Research organizations related to subcontractors.
- The perspective of the Joint Venture.

**Case study.**

### WORKING & NEGOTIATING IN CHINA
1 d

- Introduction to Chinese culture.
- Political, economic and cultural environment in China.
- Traditional values and those of future generations.
- Understanding cultural differences.
- Communicating effectively with the Chinese.
- Multicultural context project management.
- Negotiating with the Chinese.
- Realizing purchases in China.
- IP protection in China.
- Key factors for success.

**Case study.**

Reference: MOT/SINGMP-E  -  Only available as an In-House course.
Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/SINGMP. Please contact us for more information.
Powertrain Project Management

Level: FOUNDATION

Purpose
This course provides an overview of powertrain project management methodologies, tools and processes in order to build and manage a new project.

Audience
R&D engineers, managers, executives who have to participate in a project team or lead powertrain projects.

Learning Objectives
Upon completion of the course, participants will be able to:
- understand the basic notions of project management,
- understand specificities of powertrain project management,
- master the tools, processes and methodologies required to successfully manage a new project.

Prerequisites
No prerequisites for this course.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

ORGANIZATION
Life cycles of a powertrain project.
Contractor and supervisor.
Organization of powertrain projects.
Breakdown: WBS and OBS, timing and validation of projects by milestones.
Founding documents: from the product plan to the specifications of the project, contracting documents in a new project.
Introduction to systems engineering.
Planning: repositories and development plan, work scheduling (PERT/Gantt chart), management of the planning/critical path, resource management and load smoothing.
Budget and profitability: planned resources and compliance with the objectives, evaluation of the budget and management of the risks and opportunities, calculation of profitability of the project, framing of the project.

POWERTRAIN PROJECT MANAGEMENT
Steering and control of deadlines.
Steering and control of the costs.
Steering and control of quality.
Steering and control of the risks.
Requirements management process.
Configuration management.
Diversity management.
Steering a cooperation project between manufacturers.
Key features: dashboard and key indicators.
Visual management.
Supplier relationship management.
Closing a project (assessment of a project and capitalization).

ROLE OF THE PROJECT LEADER
Role of the project leader.
Leadership.
Best managerial practices.
Resistance to change.
Conflict management.
Information management.
Negotiation.
Intercultural management.
Management of people: recruitment & induction, delegation, communicate with your team, managing people’s problems, attendance management, stress management, training your staff, coaching, change management within your teams, management of the culture of the organization within the teams.

Certifications.

Reference: MOT/MGTP-E
This course is also available in French: MOT/MGTP. Please contact us for more information.

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

ml.contact@ifptraining.com
## Lean Management & Lean Engineering

### Purpose
This course provides a deeper knowledge and competencies on methodologies for implementing Lean Management and Lean Engineering and making the critical leap from the conventional business focus to the value-stream focus of optimizing the flow of value.

### Audience
R&D engineers, managers, executives who would like to implement Lean Management and Lean Engineering in their organizations.

### Learning Objectives
 Upon completion of the course, participants will be able to:
- understand the basic notions of lean management and lean engineering,
- identify waste in any organization,
- know the tools associated with lean,
- diagnose your own organization,
- understand how to implement lean management and lean engineering role playing.

### Prerequisites
No prerequisites for this course.

### Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

### Course Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INTRODUCTION</strong></td>
<td></td>
</tr>
<tr>
<td>History of lean.</td>
<td></td>
</tr>
<tr>
<td>Introduction to Lean Management/Lean Engineering/Lean Manufacturing/Lean Thinking.</td>
<td></td>
</tr>
<tr>
<td>Lean management only in automotive industry?</td>
<td></td>
</tr>
<tr>
<td><strong>CHANGE MANAGEMENT</strong></td>
<td></td>
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<tr>
<td>Why do we decide to change? Why have a lean approach? Benefits, challenges and difficulties. Environmental analysis.</td>
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<tr>
<td>Stakeholder analysis.</td>
<td></td>
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<tr>
<td>Organizational culture: practices become habits and then later an established culture. Overcoming barriers to change. Developmental change management. Transformational change management.</td>
<td></td>
</tr>
<tr>
<td>Change analysis and communication: communicating the basis to reach the change, difficulties of communication, emission and perception filters, communication styles, difference between facts/opinions, interpretation, top down and bottom up communication, effective communication (solicit and act upon feedback, recognize the human element in the change…), executive support.</td>
<td></td>
</tr>
<tr>
<td>A clear vision for the change management process. Sponsor the change. Management “model”. Create a structure to support the change. Employee involvement for Effective Change Management: involving the people/teams, build measurement systems… Role playing.</td>
<td></td>
</tr>
<tr>
<td><strong>LEAN MANAGEMENT OVERVIEW</strong></td>
<td></td>
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<tr>
<td>Kaizen: history, benefits, implementation - Value definition: the voice of the customer.</td>
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<tr>
<td>Unproductiveness: Muda, Muri, MuraBasic Problem Solving tools: 5 Whys, Ishikawa diagrams, pareto, brainstorming, selecting solutions…</td>
<td></td>
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<tr>
<td>Key tools overview: 5S, value stream mapping, process mapping, SMED (Single Minute Exchange of Dies), TPM (Total Productive Maintenance).</td>
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<tr>
<td><strong>VALUE STREAM MAPPING</strong></td>
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<tr>
<td>Variability: why reduce variability? Stock and time absorbers, control and smooth the load. Just in time: pulled vs pushed flows, flows manage the process, think system and not final product. Faultless or Jidoka.</td>
<td></td>
</tr>
<tr>
<td>Value stream mapping (VSM Methodology): process mapping, value creation flow (SIPOC diagram), constructing the “Current State Map” and the “Future State Map”, “Future State” implementation strategy development and deployment, material &amp; information flow analysis, how VSM can support the change? VSM Product Development is so different…</td>
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<tr>
<td>Role Playing.</td>
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<tr>
<td><strong>CONTINUOUS IMPROVEMENT CULTURE: PDCA SPIRIT</strong></td>
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<tr>
<td><strong>STANDARD</strong></td>
<td></td>
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<tr>
<td>Global cycle of improvement. The standard: basis of continuous improvement. Goals and expected results. Role playing.</td>
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<tr>
<td><strong>LEAN MANAGEMENT DEPLOYMENT</strong></td>
<td></td>
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<tr>
<td><strong>LEAN ENGINEERING VS LEAN MANUFACTURING</strong></td>
<td></td>
</tr>
<tr>
<td>Lean product development system: the 13 principles of J. Liker: VOC, Chief Engineer, Set Based…</td>
<td></td>
</tr>
</tbody>
</table>

Reference: MOT/LMGT-E  
Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/LMGT. Please contact us for more information.
## Systems Engineering

**Level:** FOUNDATION

### Purpose

This course provides a deeper knowledge and competencies on processes and methodologies of systems engineering and an overview of powertrain project management.

### Audience

R&D engineers, managers, executives who have to develop a new product or a new powertrain.

### Learning Objectives

Upon completion of the course, participants will be able to:

- Master the basic notions of systems engineering,
- Understand specificities of systems engineering in a powertrain project,
- Know the tools, processes and methodologies required to develop a new powertrain.

### Prerequisites

No prerequisites for this course.

### Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

### Course Content

<table>
<thead>
<tr>
<th>Module</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td><strong>FUNDAMENTALS OF SYSTEMS ENGINEERING</strong></td>
<td>0.5 d</td>
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<tr>
<td>History of Systems Engineering.</td>
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<tr>
<td>System definition.</td>
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<tr>
<td>Life cycle.</td>
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<tr>
<td>Engineering system.</td>
<td></td>
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<tr>
<td>Engineering system in automotive industry.</td>
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<tr>
<td>Processes and objects (product, process, service).</td>
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<tr>
<td>V cycle: engineering (specify, design), physical parts, integration (integrate, validate, justify).</td>
<td></td>
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<tr>
<td>Other methods of product development.</td>
<td></td>
</tr>
<tr>
<td><strong>TREE DECOMPOSITION OF A NEW SYSTEM</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td>A system tree.</td>
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<tr>
<td>Product development tree and decomposition by levels.</td>
<td></td>
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<tr>
<td>Development process tree.</td>
<td></td>
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<tr>
<td>Associated systems.</td>
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<tr>
<td>Design by steps/rank of maturity.</td>
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<tr>
<td>Simultaneous development of the product and the process.</td>
<td></td>
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<tr>
<td><strong>ENGINEERING PROCESS</strong></td>
<td>1 d</td>
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<tr>
<td>Define the need.</td>
<td></td>
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<tr>
<td>Specify: define the requirements (technical specification).</td>
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<tr>
<td>Design from a functional and organic point of view a new system to meet the requirements: internal functional analysis, external functional analysis, FMEA, functional architectures, organic architectures and interfaces.</td>
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<tr>
<td>Evaluation and optimization.</td>
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<tr>
<td>Integration and validation.</td>
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<tr>
<td><strong>PROJECT MANAGEMENT PROCESS</strong></td>
<td>0.5 d</td>
</tr>
<tr>
<td>Product and process planning.</td>
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<tr>
<td>Steering and control of deadlines.</td>
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<td>Steering and control of costs.</td>
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<tr>
<td>Steering and control of quality.</td>
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<tr>
<td>Steering and control of risks.</td>
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<tr>
<td>Requirements management: process from the need for the client to the requirement.</td>
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<tr>
<td>Configuration management.</td>
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<tr>
<td>Diversity management.</td>
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<tr>
<td><strong>APPLICATION ON A CASE STUDY</strong></td>
<td>0.5 d</td>
</tr>
</tbody>
</table>

Reference: MOT/INSYST-E. Only available as an In-House course. This course is also available in French: MOT/INSYST. Please contact us for more information.

Contact: ml.contact@ifptraining.com

www.ifptraining.com
Purpose

This course provides designers of automotive systems with a deeper knowledge on functional safety in order to select the right architecture for the powertrain. For example, functional safety ISO 26262 standard or VDA state of the art modify engines or gearbox technologies.

 Audience

Engineers, managers and technicians involved in the development of mechatronic systems and powertrains, from design to after-sales who want to incorporate in the design and utilization the principles of functional safety.

Learning Objectives

Upon completion of the course, participants will be able to:

- identify risks in mechatronic systems and in particular powertrain systems (engine and gearbox),
- understand the risks of the system over its life in all its aspects: hardware, software and interfaces,
- develop and implement a process of building a safe operating architecture (specification and validation) adapted to the context of the project and the criticality of the identified risks,
- develop or validate a case study for safety,
- identify key regulatory requirements and current standards for safety.

Ways & Means

- Interactive training with real life examples.
- Pedagogy based on workgroups and exercises.
- Practical examples of risk analyses on spark ignition and diesel engines and on automatic transmissions.
- Supports are adaptable to all problems that students will face in their professional life.

Prerequisites

No prerequisites for this course.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

5 days

INTRODUCTION TO ENGINE SAFETY

1 d
- Definitions and basics.
- Preliminary risk analysis.
- Analysis of failure modes and effects analysis (FMEA, FMECA).
- Reliability diagram.
- Failure trees.
- Trading risk.
- Development of specific problems to mechatronic systems.
- Basic principles of engineering systems.
- Legislative and regulatory framework.
- Safety state of the art.

SAFETY DEVELOPMENT IN A PROJECT

0.5 d
- Key steps in a system construction and validation.
- Integration of these steps in an engineering system process.
- Adaptation of the process to the project requirements.

DESIGNING A SYSTEM ARCHITECTURE WITH FUNCTIONAL SAFETY

0.5 d
- Identification, assessment and prioritization of mechatronic systems risks.
- Objectives declination to systems and sub-systems, hardware and software components.
- Selection and evaluation of architectures: selection and evaluation of components, systems and equipment aspects, specific aspects software.

DESIGNING POWERTRAIN WITH FUNCTIONAL SAFETY

2 d
- Practical case studies: ignition engine, diesel engine and automatic gearbox.
- Identification, assessment and prioritization of risks in a powertrain.
- Objectives declination to systems and sub-systems, hardware and software components.
- Selection and evaluation of powertrain architectures related to safety.
- Selection and evaluation of powertrain components strips to safety.
- Use of functional safety tools in a powertrain design (failure trees, FMEA...).
- Taking into account the safety state of the art: VDA case.
- Application of ISO 26262, ASIL quotes.

SAFETY FORMALIZATION & REQUIREMENTS

0.5 d
- Writing a safety specification.
- Contractual precautions.

SAFETY ANALYSIS & VALIDATION OF PERFORMANCE

0.25 d
- Main means of assessing the performance of RAMS (reliability, availability, maintainability and safety).

TREATMENT & TAKING INTO ACCOUNT THE RETURN OF EXPERIENCE

0.25 d
- Use of the life series and system development followed: interest and limitations.
- Capitalization of life series and development to improve the predictive assessment of the RAMS.
- The existing databases and their limitations.
Introduction to Aeronautics & the Astronautics

**Level:** DISCOVERY

**Purpose**
This course provides beginners in aeronautics and space with a general culture that promotes understanding between different jobs in these fields. This course deals with the main aircrafts (aircrafts, drones, helicopters, rockets) and their technologies. It also helps people understand the functions of engines in the overall context of the aircraft’s functions.

**Audience**
Engineers and technicians who wish to broaden their knowledge or to develop a general knowledge in the fields of aeronautics and space, and in particular in the field of propulsion.

**Learning Objectives**
Upon completion of the course, participants will be able to:
- know the general context of the aeronautics and space,
- master the basic principles and major phases of flight,
- understand the aircraft principles of operation and types: airplanes, UAVs, helicopters and rockets,
- understand the architectures of aircrafts and of their components and operating constraints,
- know the main services of aircrafts,
- understand engine components and their operation,
- know the main stages of life thrusters,
- know technologies and their operation related to the production of energy on board APU (Auxiliary Power Unit).

**Ways & Means**
This training course is an introduction to air and space domains and gives an overview of technologies and issues related to these areas illustrated by real examples.
- Basically interactive, it addresses the main technical fields of aeronautics and astronautics.

**Prerequisites**
No prerequisites for this course.

**Expertise & Coordination**
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

**Course Content**

**INTRODUCTION TO AERONAUTICS**
Types of aircraft: the jet age, propeller driven airplanes (piston and turbo-powered), helicopters and convertible.
Technology: technical description of an airplane, architecture, livability, skilled, types of propellants.
Avionics and cockpit functions.

**INTRODUCTION TO ASTRONAUTICS**
History of space conquest.

**INTRODUCTION TO HELICOPTERS**
Convertible: principle, flight controls.
Physical phenomena and technologies.

**INTRODUCTION TO FLIGHT MECHANICS & TO FLIGHT QUALITY OF AIRCRAFTS**
Teaching of basic techniques of flight characteristics (performance and flight qualities) and the various limits of the flight envelope of the aircraft.

**INTRODUCTION TO ON-BOARD CIRCUITS OF AIRCRAFT**
Aircraft systems: air conditioning, pneumatic, oxygen, water, electrical, hydraulic, fire detection and fuel. Tank inerting.

**INTRODUCTION TO AERONAUTICAL PROPULSION BY TURBO ENGINES**

**INTRODUCTION TO AERONAUTICAL PROPULSION BY PISTON ENGINES**

**INTRODUCTION TO PLANE CONCEPTION**

**INTRODUCTION TO DRONES (UAVS)**
Tank inerting.

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Aircraft systems: air conditioning, pneumatic, oxygen, water, electrical, hydraulic, fire detection and fuel. Tank inerting.

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**INTRODUCTION TO PLANE CONCEPTION**

**INTRODUCTION TO DRONES (UAVS)**
Tank inerting.

Reference: MOT/INTAERO-E

This course is also available in French: MOT/INTAERO. Please contact us for more information.

Contact: ml.contact@ifptraining.com

1 This course is also available as an In-House course.
Aircraft Turbo Engines

Course Content

INTRODUCTION TO AIRCRAFT TURBO ENGINE SPECIFICATIONS

Aeronautical technology reminders. Reminders an airplane and a helicopter structure. Reminders on the principles of operation. Positioning technique: positioning technical turbo engines (ramjet, pulsejet, turbojet, turboprop and turboshaft) in the world of aviation engines; type of use (propulsion and auxiliary power generation), conditions of use, range of power, efficiency propulsion, aircraft type associated.

Issues and context: consumption, noise, mass, specific power, reliability, safety, durability, performance, maintenance, integration, pollution, cost of manufacturing.

Engines mission profiles by type of aircraft and type of aircraft operations. Stages of life. Operating points, operating times. Definition of power requirement. Stabilized and transient operations related to flight mechanics. Influence of the environment: altitude, pressure, temperature, speed, ice, resistance to damage (lightning, obstacles, etc.).

Specifications for auxiliary power generation unit (APU).

Design and production: digital model, the various materials used in aircraft piston engines and their locations, assembling and producing.

Regulation and certification.

AIRCRAFT TURBO ENGINE PERFORMANCE

Detailed operation of turbo engines: technology and operation; focus on the operation of turbojet, turbofan and turboprops.

Turbo engines performance: Brayton thermodynamic cycle; thermal and propulsive efficiency; calculating results; parameters optimization, bypass ratio effect; application to the study of a turbojet and a turboprop; design of a turbojet and turboprop; effect of engine integration; impact of architectural choices and choice of materials; performance depending on the mission profile of the flight; calculation exercises and sizing.

TURBO ENGINE COMPRESSORS

Reminders of air flows: physical properties, boundary layer, shock wave, similar problems.

Profiles: geometrical, aerodynamic, stall, transonic conditions. Gas velocity mach. Notion of static pressure, dynamic and total pressure.

Reminders on the principles of compressors: conservation of mechanical energy, energy balance of compressible fluids, taking account of losses and energy transfers; adiabatic compression and actual compression.

Aeronautical technology compressors and aviation fans: operating principles, features, characteristics, changes in pressure and temperature, relative velocity and absolute axial and radial in the benchmark, aerodynamic compressors, compressor field, pumping and remedies, steering wheel input, variable-pitch stator, discharge valve, exercises calculation and dimensioning.

TURBO ENGINES COMBUSTION CHAMBER


Type of fuel for aviation applications: formulation and specifications, biofuels and aviation.

Technology and operation of a combustion chamber: specifications; constraints; combustion chambers architectures; injector (pre-spray); room reverse flow; cooling of the combustion chambers; dilution rate; release of energy, temperature, pressure, emissions in a combustion chamber; exercises calculation and dimensioning.

TURBO ENGINES COMBUSTION TURBINES

Reminders on the principles of turbines: relaxation adiabatic and real relaxation, characteristics of turbines, control principles, energy balance.


Cooling blades and discs. Creep and corrosion. Exercises calculation and dimensioning.

AUXILIARY SYSTEMS & PLATFORMS

Internal systems: air system (cooling...), fuel system, lubrication system, control system and anti-icing, box accessories.

Start ignition: boot, re-ignition.

The nacelle: air intakes, engine mounts and nozzles.

Air inlet: functional, sonic and subsonic operation, design parameters; divergent, additional air intake, supersonic air intake, sock.

Nozzle: convergent, convergent-divergent, variable section; inner cone; noise attenuators; afterburner.

Engine integration, engine maintenance.

TURBO ENGINE EVOLUTIONS

Issues: improved performance (thermal efficiency, propulsion efficiency and specific fuel consumption, pollutants, noise, vibration).

Technological developments: double Turbofan body. Turbofan with gearbox, open rotor, pusher and puller configurations, energy recovery, intercooling; evolution materials; generations N +1, N +2 and N +3 aircraft and propulsion aviation projects.

Level: FOUNDATION

Purpose

This course provides newcomers and staff working in the field of aeronautics with a deeper knowledge on characteristics of the main engine operation of aircrafts (airplanes and helicopters) and technologies. It gives an overview of the design of turbo engines.

Audience

Engineers, managers and technicians wishing to broaden their knowledge of turbo engines (ramjet, pulsejet, turbojet, single and double flow turbojet with single, double and triple bodies, turboprop and turboshaft powering aircrafts or helicopters) for propulsion and auxiliary power generation.

Learning Objectives

Upon completion of the course, participants will be able to:

- know the needs and constraints related to aircraft turbo engines based on their use,
- know the main stages of life of aircraft turbo engines in propulsion and auxiliary power supply,
- master the basic principles and specifications of turbo engines,
- understand the components characteristics of aircraft turbo engines,
- understand the operation of the elements constituting the jets and turboprops,
- calculate simple characteristics and parameters of a turbo engine,
- understand and know the certification requirements of these technologies.

Ways & Means

- This course is an introduction to aircraft turbo engines and gives an overview of technologies and issues, illustrated by real examples.
- Mainly interactive, it addresses the main technical areas of turbo engines, it focuses on the jets and turboprops for example.
- Exercises of engines and associated systems help to consolidate the knowledge.

Prerequisites

The “Introduction to aeronautics and astronautics” training course is recommended for beginners or people unfamiliar with the world of aeronautics.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose works are kept up-to-date.

Reference: MOT/MFCAERO-E  Only available as an In-House course. Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/MFCAERO. Please contact us for more information.

Contact: ml.contact@ifptraining.com

www.ifptraining.com
Aircraft Piston Engines

Course Content

INTRODUCTION TO AIRCRAFT ENGINE SPECIFICATIONS

Reminders of aviation piston engines: generic technical definitions, architectures, general operating principles, examples of use.

Technical positioning of piston engines in the world of aviation engines. Type of use, conditions of use, range of power, efficiency propulsion, aircraft type associated.

Issues and context: consumption, noise, mass, specific power, supercharging, reliability, the safety, durability, performance, maintenance, integration, pollution, the cost of manufacturing, meaning of life vs cost.

Aeronautical technology reminders, reminders airplane and helicopter structures. Reminders on the principles of operation.

Course Content

2.1 INTRODUCTION TO AIRCRAFT ENGINE SPECIFICATIONS

0.5 d

Reminders of aviation piston engines: generic technical definitions, architectures, general operating principles, examples of use.

Technical positioning of piston engines in the world of aviation engines. Type of use, conditions of use, range of power, efficiency propulsion, aircraft type associated.

Prerequisites

‘Introduction to aeronautics and astronautics’ training course is recommended for people outside the world of aeronautics or beginners in this area to improve their understanding of the aircraft propulsion operation and the auxiliary systems operation and their utilization profiles.

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Aircraft Piston Engines
Hybrid & Electric Powered Aircraft

**Course Content**

**INTRODUCTION TO AERONAUTICS**
1 d
Aeronautical technology reminders. Positioning technique: type of use, conditions of use, power range, aircraft associated; products, strategies and markets. Issues and context.
Technology: two classes of hybrid architectures (serial, parallel); power branching systems, electrical lead. Earnings function of consumption, energy recovery, energy optimization, comparing benefits, pollution. New bodies: the engine, electric motor, inverter, converter, booster, battery. Panorama, techno-economic assessment and conclusions.
Mission profiles: mission profiles of electric and hybrid engines by kind of aircraft and aircraft operations; stages of life; operating points.
Definition of power requirement. Stabilized and transient operation related to flight mechanics. Influence of the environment: altitude, pressure, temperature, speed, ice, resistance to damage (lightning, obstacles etc.). Specifications for auxiliary power generation unit (APU). Electrification engines: using electric actuators instead of hydraulic and pneumatic traditional aeronautical combustion engines.
Design and production: regulation and certification.

**ON BOARD ENERGY STORAGE SYSTEMS**
0.5 d
Electrochemical battery; principle of operation, characteristics and performance of different technologies (nickel-cadmium, nickel hydrogen, lithium ion, lithium polymer…). Supercapacitors: principle and performance. Integration into an aircraft. Fuel cells.

**POWER ELECTRONICS**
0.5 d
Power components: MOSFET, IGBT, SiC, NGa…
Electronic structures of power: DC-DC converters, DC-AC…
Power characteristics, layout constraints, thermal and vibration aspects. Electromagnetic compatibility.
Circuits involved in the making of aircraft: electrical, hydraulic, air conditioning, oxygen, icing and fuel, as well as the main organs that compose them.

**ELECTRIC MOTORS**
0.5 d
Different technologies of electric motors: principle of operation, characteristics, performance, evolution. Layout constraints: compact cooling; examples of applications on aircraft.

**ELECTRIC & HYBRID ENGINE MANAGEMENT**
0.25 d
How to order electric motors, various converters? Which physical principles? For what?
Main functions related functions.

**HYBRID CONTROL OF ROCKET & ENERGY MANAGEMENT**
0.5 d
Energy flow and energy supervision.
Objectives and constraints: consumption, energy balance, energy recovery, boost function, validation. Techniques: empirical tests, aircraft application case, proposed improvements to empirical controllers, optimal controllers.
Synthesis and validation of controllers: system usage models, optimization methods.

**THERMAL MANAGEMENT**
0.25 d
Thermal management of electrical components: battery, electrical machines, power electronics.

**ELECTRIC & AUXILIARY POWER PRODUCTION**
0.25 d

**AIRCRAFT ENGINES ELECTRIFICATION**
0.25 d
Electrical actuator: context, issues, technologies, application examples.

**Ways & Means**
Mainly interactive, supported by real examples, it addresses the main technical areas of electrical and hybrid aircraft engines.

**Prerequisites**
The "Introduction to aeronautics and astronautics" training course is recommended for people new to the world of aeronautics or beginners in this area to improve their understanding of the aircraft propulsion and auxiliary systems operations and their utilization profiles.

**Audience**
Engineers, managers and technicians wishing to improve their knowledge of aerospace alternatives in electrical and hybrid propulsion systems and aeronautical combustion engines electrification.

**Level:** FOUNDATION

**Purpose**
This course provides newcomers and staff working in the field of aeronautics with a deeper knowledge on the new ways (based on electrification) which the world of aviation is moving towards concerning propulsion or auxiliary power generation. It also covers the electrification of aircraft combustion engines to replace traditional pneumatic or hydraulic actuators.

**Learning Objectives**
Upon completion of the course, participants will be able to:
- assess the needs and constraints of aircraft engines based on their utilization,
- know the general context of current hybridization and the different forms of hybridization,
- master the basic principles and specifications of hybrid and electrical propulsion systems developed for the aerospace industry,
- know the main stages of life of electrical or hybrid propulsion engines,
- know the main stages of life of hybrid auxiliary power supplies,
- know the operating principles and limits of electrical and hybrid engines, batteries and power electronics,
- understand the specific aeronautical elements constituting the hybrid and electric systems,
- know the certification requirements of these new technologies.

**Reference:** MOT/HYERO-E

**Contact:** mt.contact@ifptraining.com

www.ifptraining.com

75
Vehicle Performances
Vehicle Fuel Consumption

Level: ADVANCED

Purpose
This course provides a deeper knowledge and competencies on fuel consumption and CO2 emissions. It also deals with applications to engine management and fuel economy tuning.

 Audience
Engineers and technical staff involved in the design, development, calibration and testing of engines, needing to know how to optimize fuel consumption and CO2 emissions.

 Learning Objectives
Upon completion of the course, participants will be able to:
- identify and optimize the main engine parameters to improve fuel economy,
- design, describe and tune engine management strategies impacting fuel economy,
- manage the trade-off between vehicle performances (emissions, drivability, emissions…) and their impact on fuel economy.

 Prerequisites
IC Engine Fundamentals.

 Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

 Course Content

<table>
<thead>
<tr>
<th>Context</th>
<th>0.25 d</th>
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<tr>
<td>Regulations, incentive ans consumerist context</td>
<td>Fuel consumption and CO2 emissions (seen from manufacturers, consumers, governments).</td>
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<tr>
<td>Protocoles, intergovernmental agreements, new laws, tax incentives (Kyoto, CAFE…)</td>
<td>Fundamentals of fuel consumption.</td>
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<table>
<thead>
<tr>
<th>Energy Optimization Ways</th>
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<tbody>
<tr>
<td>Impact of the main bricks used to reduce fuel consumption</td>
<td>Energy balance of a vehicle. Bar graph example of the fuel economy impact of the “bricks”; incentives &amp; taxes.</td>
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<tr>
<td>Reduction of fuel consumption of the powertrain (gear ratios adaptation, calibration trade-off…)</td>
<td>Reduction of fuel consumption through vehicle (S Cx, light weight, management of electrical energy…).</td>
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<tr>
<td>Numerical simulation exercise.</td>
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<tr>
<td>Vehicle electrification (types and levels): Stop &amp; start, micro-hybrid, mild hybrid, full hybrid, plug-in hybrid.</td>
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<tr>
<td>Full electric vehicles, range extender.</td>
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<td>Which stakes? Which vehicles and when?</td>
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<th>2 d</th>
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<tbody>
<tr>
<td>Evolutions related to combustion and thermodynamics: Fuels and combustion efficiency: calorific power and energy density, alternative fuels, fossil reserves and consequences on automotive technology evolution. Thermodynamical efficiency (volumetric ratio, unit cylinder capacity, number of cylinders…).</td>
<td>Cycle efficiency, high pressure loop, low pressure loop.</td>
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<tr>
<td>Engine downsizing.</td>
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<tr>
<td>Evolutions related to mechanical losses: Mechanical efficiency (engine and gearbox) and optimization ways:</td>
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<tr>
<td>- lubrication by oil, cooling system,</td>
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<tr>
<td>- components: geometry (piston skirt, piston rings…), weight reduction, friction losses, surface finish, tribology,</td>
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<tr>
<td>- optimization of combustion engine for hybrid propulsion use.</td>
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<tr>
<td>Thermomanagement.</td>
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<tr>
<td>The objectives of thermomanagement: friction reduction, emissions management, fuel consumption management.</td>
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<tr>
<td>The “bricks” of thermomanagement, use and impact.</td>
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<tr>
<td>Numerical simulation exercise.</td>
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<thead>
<tr>
<th>Engine Management &amp; Calibration</th>
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<tbody>
<tr>
<td>Introduction to engine management.</td>
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<tr>
<td>Trade-off strategies: fuel economy/reliability, or fuel economy/consumption/driveability, or fuel economy/ emissions/catalyst storage, fuel economy/max load performances.</td>
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<tr>
<td>Inter-performance trade-off and impact on fuel economy.</td>
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<tr>
<td>FE display on dashboard.</td>
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<tr>
<td>Data spread/survivability.</td>
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<tr>
<td>Homologation and conformity on production (COP).</td>
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<table>
<thead>
<tr>
<th>Vehicle &amp; Powertrain Electrification</th>
<th>1.5 d</th>
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</thead>
<tbody>
<tr>
<td>Energy optimization: Operating point of powertrain; management of vehicle performances trade-off.</td>
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<tr>
<td>Optimization rules, help to user’s drive.</td>
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<tr>
<td>Calibration and optimization: Energy management law.</td>
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<tr>
<td>Optimization criteria, investigation to optimum.</td>
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<tr>
<td>Base optimization, off-line optimization, on-line optimization.</td>
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<tr>
<td>Impact on fuel consummation: homologation/urban use/mixed use.</td>
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<tr>
<td>Parametrical study based on numerical model and AMESIM simulation.</td>
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</table>

Reference: MOT/PRESTAC-E  Only available as an In-House course.
Contact: ml.contact@ifptraining.com
This course is also available in French: MOT/PRESTAC. Please contact us for more information.

www.ifptraining.com
Vehicle Performances

Level: ADVANCED

Purpose

This course provides a deeper knowledge and competencies on vehicle performances with spark ignition and diesel engines.

Audience

Engineers and technicians in charge of development activities (calibration or design of functions, systems or components) having an impact on full load performances.

Learning Objectives

Upon completion of the course, participants will be able to understand:

- the fundamentals of the combustion physics, filling and injection, in order to improve efficiencies and performance,
- how the gasoline and diesel fuel characteristics affect the engine behavior,
- the strategies of engine management and its impact on engine performance,
- the link between customer attributes and design & development activities.

Prerequisites

IC Engine Fundamentals.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

3 days

INTRODUCTION

0.25 d

V cycle.
Torque (instantaneous, average), power, notion of load, use curve, cycle engine work, indicated mean effective pressure (IMEP), break mean effective pressure (BMEP), friction mean pressure (FMEP), mean piston speed, thermal load and specific power.
Overall efficiency, combustion efficiency, thermodynamic efficiency, cycle efficiency and mechanical efficiency.
Filling and volumetric efficiency.

PERFORMANCES: COMBUSTION & LIMITS

1 d

Fundamentals of combustion:
Combustion: combustion equation, determining the stoichiometric quantity and the air/fuel ratio, calorific value. Pollutants formation, flammability limit, auto-ignition delay.
Aerodynamic air/fuel in combustion chamber vs swirl & tumble.
Comparison between gasoline and Diesel engines: combustion process (load control, preparing the air-fuel mixture, initiation, expansion, pollutants formation, exhaust gas recirculation (EGR), vibrations and noise origins), full load performance limits (knocking, mechanics, thermo-mechanics, exhaust temperatures), in-use efficiency (downsizing, downspeeding).
Fuel features: cetane number (diesel), octane number (gasoline).
Full load limits linked to the engine architecture: knocking, maximum cylinder pressure, exhaust temperature, heat flow for the holding of cylinder head, piston…, compressor output temperature, blow by and dilution.
Full load limits linked to the visual consequences of the combustion (black smoke in diesel…).
Full load limits linked to thermo mechanics constraints of the components: injection system (injection pressure and temperature (HP pump) and nozzle temperature), turbocompressor.

FUEL INJECTION SYSTEM

0.25 d

Diesel: injector-pump, common rail (solenoid, piezo with pressure amplification…). Evolutions.
Gasoline: fuel injection systems and evolutions.

CHARACTERIZATION - BREATHING & SUPERCHARGING

0.5 d

Performances: potential of the different technologies, parameters affecting the performances.
Admission and exhaust back pressure losses.
Breathing: volumetric efficiency, timing, acoustic inlet (Kadenacy effect, ¼ wave…), and exhaust (3Y manifolds, separate exhaust lines…) optimization.
Link between breathing and performances.
Compromise between Cf β/swirl (diesel).
Variable distribution systems.
Supercharging: supercharging types, turbocharger operation and technology, mapping (characteristic fields), adaptation to engine, trade-off to carry out.
Operating of turbochargers: geometrical characteristics, flow control, cooling energy.
Map pressure-flow of the compressor and operating limits. Characteristics of turbine, saturation.
Turbocharger parts technology: materials, lubrication, reliability, geometry fixed /variable, twin scroll, double/triple supercharging.
Adaptation of a turbocharger on an engine: choice of the compressor and the turbine according to the characteristics and performance of the engine.

INTRODUCTION TO ENGINE MANAGEMENT SYSTEM

0.75 d

Introduction to engine management (torque structure).
Stabilized conditions: full load calibration.
Powertrain protections: gearbox, transmission; mechanical resistance of the engine and components (turbocharger over speed, dilution, etc.); thermal resistance of the engine and components (calibration protections to manage temperature of fuel, water, air, etc.).
Diesel: transient conditions (smoke mapping, overboost and overfueling, calibrations of the turbocharger), exotic conditions (hot/altitude).
Gasoline (knocking): definition/consequences of main parameters, calibrations (knocking limit, curative and preventive calibration).
Dispersions. Robustness.
Full load homologation and conformity of production.

PERFORMANCES ON VEHICLE

0.25 d

Vehicle maximum speed.
Effect of drivability calibration on the subjective perception of the client.
Effect of transmission.
Validation plan.

Reference: MOT/RESTAP-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/RESTAP. Please contact us for more information.

78
Vehicle Emissions

Level: ADVANCED

Purpose
This course provides a deeper knowledge and competencies on emissions and after-treatment systems.

Audience
Engineers and technical staff involved in the design, development, calibration and testing of engines, who need to know the mechanisms of pollutants formation and current and future exhaust gases after-treatment systems.

Learning Objectives
Upon completion of the course, participants will be able to:
- know the fundamentals on the physics of the combustion and the mechanisms of pollutants formation,
- master the contribution of alternative engines to atmospheric pollution phenomena,
- know the regulations restrictions,
- know the nature of the emitted pollutants,
- use emission reduction levers at source,
- know testing methodologies, the standard tools used to measure pollutants (gas analyzers, opacity meters), the kind of measurements and analyses done on exhaust gases,
- understand on board diagnostics (OBD) requirements,
- know how the gasoline and diesel fuel characteristics affect the engine behavior,
- understand the structure of engine management system and its impact on emissions.

Prerequisites
IC Engine Fundamentals.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

<table>
<thead>
<tr>
<th>Topic</th>
<th>Duration</th>
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<td>AIR POLLUTION, ROOTS &amp; CONSEQUENCES, REGULATIONS</td>
<td>0.5 d</td>
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<tr>
<td>Primary and secondary pollutants. Regulated and non-regulated pollutants (NRP).</td>
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<tr>
<td>Regulations: CO₂ emissions, WLTP. Influence of vehicle characteristics and powertrain adaptation on emissions (cost down, inertia class, gear ratios…).</td>
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<tr>
<td>Homologation. Production conformity.</td>
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<tr>
<td>ATMOSPHERIC PHENOMENA</td>
<td>0.25 d</td>
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<tr>
<td>Air quality: space (local or global) and time scales. Consequences and impacts. Phenomena: ozone layer, greenhouse effect, acid rains, photochemical smog…</td>
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<tr>
<td>Air quality standards, regulations applied to the car emissions and approval cycles.</td>
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</tr>
<tr>
<td>TESTING METHODOLOGY - MEASUREMENTS ON ENGINES &amp; EXHAUST GAS ANALYSIS</td>
<td>0.25 d</td>
</tr>
<tr>
<td>EMISSIONS REDUCTION LEVERS AT SOURCE</td>
<td>1 d</td>
</tr>
<tr>
<td>Diesel: combustion, mechanisms of pollutants, influence of engine parameters, operating limits, injection equipment, air loop engine management, fuel impact, calibration.</td>
<td></td>
</tr>
<tr>
<td>Gasoline: combustion, mechanisms of formation of pollutants, influence of engine parameters, operating limits, injection equipment, air loop engine management, fuel impact, calibration.</td>
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<tr>
<td>EXHAUST GAS AFTER TREATMENT OXIDATION &amp; TRI-FUNCTIONAL CATALYSIS</td>
<td>0.75 d</td>
</tr>
<tr>
<td>Oxidation and tri-functional catalysis: Automotive exhaust catalysis: catalytic reactions, mechanisms, catalysts, precious metals, performance criteria, functional definitions (conversion rate, after-treatment related constraints, gasoline and Diesel). Oxidation catalysis: efficiency, field, initiation, conversion rate, case of methane, sulfur and particles oxidation. Tri-functional catalysis: stoichiometric conditions, air/fuel ratio control, cold conditions (HC, exhaust thermal management), high power loop opening. Catalysts ageing: ageing nature, thermal (temperature and sintering), chemical (poisoning), by the accumulation of deposits coming from the lubricants, the fuels or the additives. Functional limit of catalysts ageing. Nitrogen Oxides Treatment: NOx traps: operating principle (storage mechanisms, range of temperatures to use, rich mixture reduction phase), trap desulfurization. Selective reduction catalytic (SCR): by ammonia, urea injection strategy, use restrictions. “Clean-up” catalysts. Particulate filter: filtration element structure and composition regeneration strategy either by fuel additive, fuel born catalyst or by Catalytic diesel Particulates Filter (CdPF). Use of the 5th or the 7th injector. Installation on the vehicle: evolution towards the 4-way catalysis: in the same converter, combining the particulate filter of a nitrogen oxides treatment system (SCR or non-trap) with an oxidation catalyst.</td>
<td></td>
</tr>
<tr>
<td>DIAGNOSIS &amp; OBD REGULATIONS</td>
<td>0.25 d</td>
</tr>
<tr>
<td>Introduction to the OBD in France and in the world. Evolutions.</td>
<td></td>
</tr>
<tr>
<td>OBD homologation. OBD validations.</td>
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</tr>
</tbody>
</table>

Reference: MOT/PRESTAE-E Only available as an In-House course.

This course is also available in French: MOT/PRESTAE. Please contact us for more information.

Contact: mt.contact@ifptraining.com

www.ifptraining.com
Drivability

Level: ADVANCED

Purpose
This course provides a deeper knowledge and competencies on engine design, management and calibrations in order to optimize drivability.

Audience
Engineers and technical staff working in relation with engine departments and needing to know the vocabulary, the physics fundamentals, engine management and calibrations of drivability.

Learning Objectives
Upon completion of the course, participants will be able to understand:
- drivability from an engineering perspective,
- how engine management functions and its impact on drivability,
- the physics and the parameters used in the engine that improves drivability,
- the vehicle reactions that cause customer drivability concerns for the engine and vehicle systems and interfaces.

Prerequisites
IC Engine Fundamentals.

Expertise & Coordination
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

Course Content

INTRODUCTION
V Cycle.
What is drivability?
List of subsystems that affect drivability.
Highlight the impact of future technologies.
Explain how drivability is measured.
How these measurements are correlated back to customer concerns?
Formalization of the requirements on drivability.
Between specification and validation of drivability.

ENGINE MANAGEMENT SYSTEM & CALIBRATION
Introduction to engine management (torque structure).
Drivability strategies in the torque structure.
Drivability target settings.
Classification of driving modes.
Specifications of engine management.
Compromise between attributes.
Calibrations.

DRIVABILITY
Drivability target definition (engine speed fluctuation, response delay…).
Drivability within the vehicle development process.
Driving modes (Tip in/Kick down/Take off…): compromise between attributes.
Anti-jerk and LTC: Load transient Control.
Engine management system.
Calibration and drivability release.

IDLE SPEED REGULATION
Idle in stabilized conditions.
Idle in transient conditions.
Engine management system.
Calibration and validation.

DRIVABILITY: OTHER ATTRIBUTES
Anti-stall strategy.
RVV/LVV strategies.
Climatization cut-off strategies.
Engine protection strategies (brio effect).
Other strategies (Easy Move, ESP…).
Engine control.
Calibration and validation.

This course is also available in French: MOT/PRESTAA. Please contact us for more information.

Reference: MOT/PRESTAA-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com
Introduction to Powertrain Modeling

Level: FOUNDATION

Purpose

This course provides an introduction and an overview of 0D/1D/2D, 3D modeling and simulation applied to powertrains. It presents the state of the art of computer simulation tools. It is also a prerequisite for Powertrain and vehicle investigations and powertrain management.

Audience

Engineers, managers and technicians working in the field of powertrains, interested in modeling and simulation for engines and gearboxes and their use for design and control. Such techniques contribute to digitally design architectures, systems, parts and controls that constitute the Powertrain.

Learning Objectives

Upon completion of the course, participants will be able to:

- Master the principles of powertrain modeling.
- Know the basics of modeling in the area of compressible and incompressible fluids, combustion, mechanics and thermals.
- Know the components of a Powertrain (0D model: modeling agencies (engines and gearboxes), components (sensors, actuators, turbochargers, valves, ducts, crankshaft, camshaft,...), circuits and fluids (water, oil, fuel, air, exhaust gases...) and systems (cooling systems, air supply systems, combustion chamber,...).
- Know the principles of most used simulation tools in the field of powertrain design.
- Use models and simulations to develop powertrains: best choices of architecture and parts designs impact the design with benefits on the powertrain and its control.

Ways & Means

- This training course is based on continuous balancing between theory and practice, knowledge and expertise.
- 0D engine model designs with Matlab-Simulink base.
- Practical case studies with 0D, 1D and 3D models.
- Simulation and operation of 1D models for purposes of system designs: air system, combustion chamber, cooling, mobile hitch.
- Implementation of 3D models for system designs: air system, combustion chamber, cooling, system of moving parts.

Prerequisites

No prerequisites for this course.

Expertise & Coordination

Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

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Reference: MOT/MSGMP-E

Only available as an In-House course.

Contact: ml.contact@ifptraining.com

This course is also available in French: MOT/MSGMP. Please contact us for more information.
**0D Powertrain Modeling**

**Level:** ADVANCED

**Purpose**
This course provides an overview of 0D modeling applied to the engine: fluids modeling, combustion modeling, thermal and mechanical modeling. It is also a prerequisite for powertrain and vehicle investigations and powertrain management. The models developed in this course are operational and directly applicable to real design applications.

**Audience**
Engineers, managers and technicians working in the field of powertrains, interested in 0D modeling and simulation for engines and gearboxes and their use for design and control. Such techniques contribute to digitally design architectures, systems, parts and controls that constitute the powertrain.

**Learning Objectives**
Upon completion of the course, participants will be able to:
- master the principles of 0D modeling;
- know the basics of 0D modeling in the area of compressible and incompressible fluids, combustion and thermals;
- know the components of a 0D powertrain model: modeling agencies, components, circuits and fluid systems;
- design and develop a 0D model of an engine;
- design and develop powertrain control strategies;
- implement and configure the components of a 0D model;
- learn the principles of different 0D simulation tools, such as Matlab-Simulink, GT-Power or AMESIM;
- use 0D models and 0D simulations to develop powertrain systems and powertrain controls.

**Ways & Means**
- This course presents the state of the art of 0D computer simulation tools.
- This training course is based on continuous balancing between theory and practice, knowledge and expertise.
- Design of complete 0D models of engine parts or engines on Matlab Simulink.
- Concrete case studies of 0D simulation.
- Simulation and exploitation of 0D models for system and control designs: air system, combustion chamber, cooling system, fuel system, mechanical engine parts.

**Prerequisites**
No prerequisites for this course.

**Expertise & Coordination**
Trainer with a high level of expertise and experience on these topics and whose skills are kept up-to-date.

**Course Content**

**INTRODUCTION TO 0D MODELING**
Basics of 0D modeling and numerical simulation. 0D simulation compared to 1D and 3D simulation in the design process of a powertrain system. Notions of model reduction 3D/1D to 0D. When can we use 0D models in a powertrain design, for what kind of studies?
Mathematical models, statistical and physical. Fundamentals of numerical simulation, numerical schemes of resolution, operating solvers, numerical errors and waste. Presentation and technical comparison of the main tools for the simulation 0D simulation Matlab-Simulink, GT-Power and Amesim.

**0D FLUID MODELING & SIMULATION**
Fundamentals of fluid modeling: conservation of mass, momentum and energy, nature of the flow, the notion of compressibility, definition of viscosity, equations “Barré Saint-Venant” and Bernouilli, flow coefficients. Problem of the propagation of pressure waves in 0D solvers and comparison software (Matlab-Simulink, GT-Power and AMESIM), operating principles and properties of the software.
Modeling components of compressible fluids: modeling pipes and volumes (air filter, plenum, headers …); modeling valves (throttle body, shutters, EGR valves); modeling turbochargers and mechanical compressors.

**0D COMBUSTION & EMISSIONS MODELING & SIMULATION**
Introduction to the modeling of combustion, heat, burning rate, creation of chemical species, chemical kinetics, the concept of self-ignition delay, knocking engine, premixed flame and diffusion flame, laminar velocity and turbulent aerodynamic, coupling combustion cycle to cycle variation, statistical aspects related to combustion models…
Combustion models: 1 zone 2 zones Eddy burn-up and barba and multi-zones, physical models and combustion rate imposed models.
Influence of combustion parameters: wealth, rates of RBG, EGR rate, the injection timing, the ignition, aerodynamic phenomena… Modeling knock.
Phenomenological modeling emissions and statistical modeling of emissions (mapping and neural networks);
Modeling components: heat transfer model, aerodynamics (turbulence), combustion models, kinematic models.
Model calibration, recalibration of combustion models.
Application to diesel: example of Diesel predictive combustion models, example of statistical models emission.
Application to gasoline: analysis and correlation of cylinder pressure, intake and exhaust; parametric study; examples of combustion models.

**0D THERMAL MODELING & SIMULATION**
Fundamentals of thermal modeling, conduction, natural and forced convection, radiation, thermal inertia, heat balance equations.
Modeling components: fluid components and combustion models incorporating thermal, heat exchangers and thermostats.
Characterization of components, thermal correlation, building materials, masses, specific heat, thickness…
Application: operation of an exchange model (EGR and CAC impact on engine air loading).

**0D MECHANICAL MODELING & SIMULATION**
Fundamentals of mechanical modeling: inertia, stiffness and damping, spring mass system complete.
Modeling components: masses, springs, dampers, friction aerodynamics, engine friction, motion conversion.
Applications: examples of a gearbox and a kinematic modeling of a vehicle; operation of the model on a driving cycle.

**0D ENGINE MANAGEMENT MODELING & SIMULATION**
Using 0D models for powertrain control. Modeling real time operating system. Numerical modeling of PID controllers.
Modeling and simulation of real-time operation systems: generation of classical synchronous and asynchronous events in motor control.
Modeling and simulation of regulators engine control strategies: example of the PID controller.
Modeling and simulation of control strategies: integration strategies, real-time system and environmental models.
0D modeling used to find the optimum requirement compromise.
Applications: design of the boost pressure regulation; design of an EGR control rate; development and calibration of engine control strategy.

Reference: MOT/MS0D-E

Only available as an In-House course.

Contact: mt.contact@ifptraining.com

This course is also available in French: MOT/MS0D. Please contact us for more information.
1D Powertrain Modeling

Course Content

1D FLUID MODELING & SIMULATION
Basics of 1D modeling and numerical simulation. 1D simulation compared to 0D and 3D simulation in the design process of a powertrain system.
Fundamentals of fluid modeling: Eulerian approach, Lagrangian Navier-Stokes equations, conservation of mass, momentum and energy, nature of the flow, boundary layer concept, the notion of compressibility, definition of viscosity, equation of state, flow coefficients, pressure wave propagation. Average flow and instantaneous flow fluctuations.
Solvers and comparison software (GT-Power and AMESIM), operating principles and properties of the software.
Modeling components of compressible fluids: modeling pipes and volumes, modeling valves, modeling boosting components.
Modeling components of incompressible fluids: modeling of hydraulic circuits, modeling pumps, taking into account the deformation of the flexible.
Determination of calibration models and components.
Application of modeling based on simulation tools GT-Power: construction of a supercharged engine with EGR and CAC model, modeling air loop, correlation, calculations and tests and registration of the model, analyzing performance.
Design and architecture: modeling of powertrain configurations, simulation of the pressure waves, parametric study.
 Injector modeling.

1D COMBUSTION & EMISSIONS MODELING & SIMULATION
Introduction to the modeling of combustion, heat, burning rate, creation of chemical species, chemical kinetics, the concept of self-ignition delay, knocking engine, premixed flame and diffusion flame, laminar velocity and turbulent combustion, coupling combustion cycle to cycle variation, statistical aspects related to combustion models...
1 zone model, 2-zone model, 3-zone model, 1D combustion model, influential parameters modeling.
1D Diesel combustion model, influential parameters modeling.
Predictive modeling of emissions (NOx, particles, HC, CO and CO2), statistical modeling programs: mapping and neural networks.
1D modeling combustion CFD models, model heat transfer, aerodynamics, combustion model, chemical models.
Operating principles and properties of the simulation software.
Modeling components: injector, cylinder, chamber geometry, piston position; heat transfer model, aerodynamics (swirl, turbulence, combustion).
Model calibration, recalibration of combustion models.
Application to Diesel: cylinder pressure analysis and correlation from the cylinder pressure measurement only; example of predictive Diesel combustion models (multi-zone).
Application to Gasoline: analysis and correlation of cylinder pressures TPA; three pressure analysis (Pcyl, Pexhaust, Pintake) for determining the rate of RBG; parametric study: influence of the rate depending on the RBG Camshaft law; examples of predictive models of combustion gas (1D, 2 zones).

1D MODELING & THERMAL SIMULATION
Fundamentals of thermal modeling, conduction, natural and forced convection, radiation, thermal inertia, heat balance equations, dimensionless numbers in heat (Prandtl, Nusselt).
Modeling components: fluid and combustion components incorporating thermal models (lines and volumes, heat roller), heat exchangers, thermostats, loss models for walls.
Characteristic of components, building materials, masses, specific heat, thickness...
Application: construction of a predictive model exchanger: EGR or CAC; characterization of virtual component bench; parametric study on bench or on integrated cooling system.

1D MECHANICAL MODELING & SIMULATION
Fundamentals of mechanical modeling: inertia, stiffness and damping torsional deformations.
Frequency approach and temporal approach.
Modeling components: masses, springs, dampers, motion conversion, reducers, trees, strength, speed, time, macro components (valves, wastegate, components of a gearbox).
Examples of 1D modeling engine design, part modeling and studies of mechanical systems: piston shafts, engine block, manifolds, cylinder heads.
Application: mass spring system: modeling approaches; examples of crankshaft torsional analysis; examples of gearbox modeling approaches; interaction and fluid mechanics (opening a wastegate under the forces of aero pressure).

Reference: MOT/MS1D-E
Only available as an In-House course.
ml.contact@ifptraining.com

This course is also available in French: MOT/MS1D. Please contact us for more information.
3D Powertrain Modeling

Course Content

3D FLUID MODELING & SIMULATION  1.5 d
Basics of 3D modeling and numerical simulation. 3D simulation compared to 0D and 1D simulation in the design process of a powertrain system. Fundamentals of fluid modeling: Eulerian approach, Lagrangian, Navier-Stokes equations, conservation of mass, momentum and energy, nature of the flow, boundary layer concept, the notion of compressibility, definition of viscosity, equation Barre Saint-Venant, flow coefficients, pressure wave propagation. Average flow and instantaneous flow turbulence. Spatial discretization, mesh, digital resolution scheme, solvers and comparison software (Star CD, Star CCM +, Fluent, AVL-Fire, Converge, Open Foam, source software), operating principles and properties of the software. Modeling components of compressible fluids: modeling pipes and volumes, modeling valves, modeling boosts components. Modeling components of incompressible fluids: modeling of hydraulic circuits, modeling pumps, taking into account the deformation of the flexible. Determination of calibration constants and components. Application of modeling with “Open Foam” simulation tool: introduction to Open Foam, principles and operation of the software; computers skills upgrade (using the Shell Linux, Linux basic commands); construction of an air circuit model, modeling of the air circuit, building skin mesh, parametric study; construction of a hydraulic model, modeling of a fuel hose, parametric study.

3D COMBUSTION & EMISSIONS MODELING & SIMULATION  1.5 d
Introduction to the modeling of combustion, heat, burning rate, creation of chemical species, chemical kinetics, the concept of self-ignition delay, knocking engine, premixed flame and diffusion flame, laminar velocity and turbulent aerodynamic, coupling combustion cycle to cycle variation, statistical aspects related to combustion models…
1 zone model, 2-zone model, 3-zone and multi-zone model. 3D combustion model, influential parameters modeling. Diesel combustion model, influential parameters modeling. Predictive modeling of emissions (NOx, particles, HC, CO and CO2), statistical modeling programs: mapping and neural networks. 3D modeling combustion CFD models, model heat transfer, aerodynamics, combustion model, chemical models. Spatial discretization, mesh, digital resolution scheme, solvers and comparison software (Star CD, Star CCM +, KIVA, AVL-Fire, Converge, Open-Foam), operating principles and properties of the software. Modeling components: modeling of jet fuel, rate of introduction of the cylinder, geometry of the combustion chamber, piston, spark and dynamic mesh of the combustion chamber. Calibration of 3D models. Generic application of “Open Foam”: creating an engine model and dynamic mesh. Diesel application of “Open Foam”: creating a diesel combustion model. Gasoline application of “Open Foam”: calculation based on a model 3D gasoline combustion.

3D MODELING & THERMAL SIMULATION  0.75 d
Open foam applications: construction of an exchanger model, parametric study on the heat exchanger model.

3D MECHANICAL MODELING & SIMULATION  0.75 d
Open foam applications: construction of an exchanger model, parametric study on the heat exchanger model.

3D MATCHING & BOUNDARY CONDITIONS  0.5 d
Good use of 3D modeling. Boundary conditions. 3D models reduction in 1D or 0D models. Coupling a 3D model to a 1D or 0D models. Application: GT-Power and Open-FOAM coupling.
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Registration

Identify on the course program the course reference, the price, the location and the dates you are interested in; as well as the contact name for registration.

So that your registration is done in the best conditions, please follow the procedure below:

- **3 weeks minimum** before the beginning of the course → register preferably on our website:
  
  https://www.ifptraining.com

  or send the fully completed registration form (downloadable on our website or available from one of our secretarial departments).

- **2 weeks minimum** before the beginning of the course → Please make the full payment
  
  - By check payable to IFP Training, 232 avenue Napoléon Bonaparte – 92852 RUEIL MALMAISON CEDEX
  - By bank transfer to IFP Training
    
    NATIXIS n° 30007 99999 04165583000 12
    IBAN: FR76 3000 7999 9904 1655 8300 012 – NATXFRPPXXX

Shout a sponsoring organization (like OPCA in France) pay for the course, please specify it on the registration form.

Do not hesitate to contact us for a late registration.

**Tuition fee includes instruction, documentation as well as meals and beverage breaks.**

**IFP Training will send to the authorized person indicated on the registration form:**

- a written confirmation by mail
- one or several invitations for the participants
- useful information about the training course (access to the training center, training hours, etc.).

**Who should you send your registration form to?**

The registration form can be sent by email, mail or fax.

It should be sent to the entity organizing the course you have chosen. This entity appears at the bottom of the course program.

All enrolments are considered as accepted orders as soon as the enrolment confirmation issued by IFP Training has been received and implies the client’s full commitment to these Terms & Conditions which prevail over all other Client documents, including general purchasing conditions.
# Your Contacts

## Exploration & Production

### Rueil-Malmaison
- **Geosciences & Reservoir Engineering**
- **Production & HSE Engineering & Project Management**
  
  232 avenue Napoléon Bonaparte
  92852 Rueil-Malmaison Cedex - France

  **Secretarial Department**
  Tel. +33 (0)1 41 39 11 60
  Fax +33 (0)1 47 08 92 83
  ep.contact@ifptraining.com

### Pau
- **Drilling & Completion**
- **Production & HSE Engineering & Project Management**
  
  Rue Paul et Henri Courteault
  64000 Pau - France

  **Secretarial Department**
  Tel. +33 (0)5 59 30 82 50
  Fax +33 (0)5 59 30 68 76
  ep.contact@ifptraining.com

## Refining & Chemicals

### Rueil-Malmaison
  
  232 avenue Napoléon Bonaparte
  92852 Rueil-Malmaison Cedex - France

  **Secretarial Department**
  Tel. +33 (0)1 41 39 11 00
  Fax +33 (0)1 47 08 92 83
  rc.contact@ifptraining.com

### Martigues
  
  Le Bâteau Blanc - Bât. C
  Chemin de Paradis
  13500 Martigues - France

  **Secretarial Department**
  Tel. +33 (0)4 42 44 43 00
  Fax +33 (0)4 42 80 61 20
  rc.contact@ifptraining.com

### Lillebonne
  
  Immeuble Futura 1
  Rue A. Desgenetais
  76170 Lillebonne - France

  **Secretarial Department**
  Tel. +33 (0)2 35 39 60 77
  Fax +33 (0)2 35 38 62 03
  rc.contact@ifptraining.com

### Solaize
  
  Rond-point de l’échangeur de Solaize
  BP3 - 69360 Solaize - France

  **Secretarial Department**
  Tel. +33 (0)4 37 37 68 20
  rc.contact@ifptraining.com

## IC Engines & Lubricants

### Rueil-Malmaison
  
  232 avenue Napoléon Bonaparte
  92852 Rueil-Malmaison Cedex - France

  **Secretarial Department**
  Tel. +33 (0)1 41 39 12 00
  Fax +33 (0)1 47 08 92 83
  ml.contact@ifptraining.com

## Economics & Management

### IC Engines & Lubricants
  
  232 avenue Napoléon Bonaparte
  92852 Rueil-Malmaison Cedex - France

  **Secretarial Department**
  Tel. +33 (0)1 41 39 10 80
  Fax +33 (0)1 47 08 92 83
  em.contact@ifptraining.com

### IFP Training Middle-East
  
  contact.middleeast@ifptraining.com
  Tel. +973 17 21 01 38

### IFP Training Congo
  
  contact.congo@ifptraining.com
  Tel. +242 (0)6 655 43 43
  Tel. +33 (0)1 41 39 12 12

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**General Contact Information:** Tel. +33 (0)1 41 39 12 12 - contact@ifptraining.com
General Terms of Sale

1. Purpose and scope

The purpose of these General Conditions of Sale (hereinafter referred to as the “GTC”) is to define, both in France and internationally:
- on the one hand, the organization and implementation of in-house training sessions by IFP Training on behalf of the Client (hereinafter the “Client”), signatory of the Training Order defined below;
- on the other hand, the general conditions for participation in the Public training sessions organized by IFP Training.

2. Order provisions

Every request is placed on the basis of an IFP Training commercial proposal (serving as the special terms for the present GTC), particularly setting specific conditions for training services to be provided, the price and the payment terms (hereafter the “Training Order”).

- For In-house training sessions

Unless indicated otherwise, IFP Training commercial proposals are valid for a three-month (3) period from the date of dispatch of the IFP Training commercial proposal to the client.

The Training Order shall be submitted by the Client at least five (5) weeks prior to the starting date of the first requested session. IFP Training reserves the right to refuse late orders.

The Training Order will be binding upon IFP Training once IFP Training has received the following documents:
- the IFP Training commercial proposal initialed on each page, with the last page containing the handwritten indication “Accepted and Agreed”, as well as the Client’s signature and commercial stamp, if any;
- these GTC with initials on each page;
- contact details of the invoice’s recipient, and all information to be contained in the invoice.

As such, the Training Order is made up of the following documents, in decreasing order of priority:
1. IFP Training commercial proposal;
2. IFP Training GTC;
3. all other documents referred to in the IFP Training commercial proposal.

Client’s acceptance of the IFP Training commercial proposal constitutes its firm and definitive commitment to the Training Order and implies the non-applicability of its own general terms of purchase, even if mentioned in the Client purchase request.

- For Public training sessions

All inscriptions to training sessions shall be carried out three (3) weeks prior to the session start date. IFP Training reserves itself the right to accept late enrolment. The number of participants per session is limited. Enrolment will be confirmed once the organization center receives a fully complete enrolment form via email, fax or mail. Incomplete enrolment forms will not be accepted. Enrolment will be final once payment has been received in full or once an acceptance certificate from a sponsoring organization has been received.

All enrolments are considered as accepted orders as soon as the enrolment confirmation issued by IFP Training has been received and implies the client’s full commitment to these Terms & Conditions which prevail over all other Client documents, including general purchasing conditions.

If the entire cost of the session is not paid two (2) weeks before the training session begins, IFP Training reserves itself the right to reopen to registration the places booked by the Client, after having informed them. If full payment is received IFP Training will, at least two (2) weeks prior to the start of the session, send a letter to the Client designated on the form to confirm their enrolment. A personal invitation will be attached to the letter and which provides all practical information about the session (schedule, directions, etc.).

3. Invoicing and payment

3.1. Price

- For In-house training sessions

Invoicing and payment schedule is defined in the commercial proposal. Unless indicated otherwise in said proposal, quoted prices are in Euros and exclusive of taxes; VAT at the applicable rate and/or any possible duties and/or taxes withheld at the source according to the applicable legislation shall be added. Prices are firm and not subject to revision.

- For Public training sessions

Enrolment fees cover training (teaching, practical activities, simulators and other IT tools, documentation, supplies) as well as break-time related costs (refreshments). And do not cover transport and accommodation.

The price on the order form is indicated in Euros, tax not included. VAT at the current rate will be added to the indicated price plus any other withholding taxes. All training sessions, once started, have to be paid in full. Upon request, IFP Training may decide to apply reduced enrolment fees for job seekers.

3.2. Payment

Payment will be made by bank transfer to the beneficiary IFP Training: NATIXIS account No. 30007 99999 04165583000 12 IBAN: FR76 3000 7999 9904 1655 8300 012 – BIC: NATXFRPPXXX

- Third-party payment organization (such as accredited collecting funds for training): if Client makes a third party pay for the training, it must so inform IFP Training at the time of the Training Order. In this case, IFP Training will make its reasonable efforts to provide the documents requested by the Client (possible translation at the Client’s expense). The Client will ensure that payment is made by that third party. In case of non-payment or partial payment by said third party for any reason whatsoever, all sums not received by IFP Training on the due date will be borne by the Client.

- For Public training sessions, the training session will only be accessible to the Client once that IFP Training has been paid in full. By check to the order of:

IFP Training - 232, Avenue Napoléon Bonaparte
F-92852 Rueil-Malmaison Cedex

Via bank transfer to IFP Training above mentioned account.

A duplicate is available provided that the Client requested it on the enrolment form.

If the Client wishes to pay using a sponsoring organization, the following procedures should be followed:
- before the start of the session, a request for direct billing should be issued and accepted;
- this shall be indicated explicitly on the enrolment form;
- the Client ensures the completion of payment by the designated organization.

IFP Training will provide the Client with all documents needed to make a sponsoring request.

If the sponsoring organization only bears part of the training cost, the remaining amount will be charged to the Client. Only payments by sponsoring organizations before the first day of training will ensure enrolment and access to the training.

If, for whatever reason, the sponsoring organization doesn’t pay, the Client will be charged the full training amount. At the end of the session IFP Training will send the sponsoring organization an invoice along with a copy of the certificate of attendance signed by the participant.

3.3 Late payment

Pursuant to the provisions of article L441-6 of the French Commercial code, all sums not paid on their due date will require Client to pay late payment penalties equal to three (3) times the French legal interest rate.
General Terms of Sale

These penalties are due until full payment. In the event of late payment, the Client will also owe to IFP Training a fixed compensation of forty (€40) Euros for collection costs. Should collection costs be higher than such fixed compensation, IFP Training can demand additional compensation from the Client by providing supporting proof.

IFP Training also reserves the right to interrupt the performance of the services if an invoice is not paid on or before the due date, without prejudice to any other recourse.

4. Cancellation and deferral - Modification of services

4.1 Cancellation and deferral conditions

► For In-house training sessions

By the Client: Any request for cancellation or deferral of all or part of the Training Order by Client shall be notified to IFP Training in writing, with acknowledgment of receipt, no later than three (3) weeks before the session date. This three (3) week delay is counted from the date of reception by IFP Training of said request.

(i) In case of deferral:

Any deferral requested less than three (3) weeks before the session date will be considered by IFP Training as a session cancellation. The conditions of (ii) or (iii) below will then apply.

(ii) In case of partial cancellation of the Training Order (i.e. cancellation of one or more sessions):

For any Training Order or part thereof cancelled while giving the required three-weeks prior written notice, the Client will only pay the expenses already incurred by IFP Training (including internal preparation costs) that cannot be deferred.

For any session cancelled between one and three (3) weeks before the session date, the Client will have to pay 60% of the price of the cancelled session.

For any session cancelled with a notice given less than one (1) week before the session date, the Client will have to pay 100% of the cancelled session’s price.

Full payment is required for every session performed, however partial. The Training Order will remain valid for all non-cancelled sessions.

(iii) In case of the Training Order’s total cancellation:

The provisions of (i) will be applicable to the entirely cancelled Training Order and to the total price of the Training Order.

By IFP Training: IFP Training reserves the right to cancel or defer any session providing a three-(3) week prior notice, by e-mail, fax or letter. No compensation will be paid to the Client but IFP Training undertakes to agree with Client on a new session date within four (4) months.

► For Public training sessions

By the Client: Cancellation by the Client shall be sent in writing to IFP Training. In the eventuality of a cancellation, even due to force majeure, less than 14 calendar days before the beginning to the session, 50% of the enrolment fee will be charged by IFP Training, except if a participant from the same company takes the participant’s place. Such a replacement must be communicated to IFP Training and confirmed by sending a new enrolment form.

In case of non-cancelled enrolments (including absenteeism or dropout), 100% of the enrolment fee will be charged by IFP Training. In case of an unforeseen departure, justified by the Client, the participant may be authorized to take part in a later session with the prior consent of IFP Training.

By IFP Training: IFP Training reserves itself the right to cancel or postpone a session, especially if there are an insufficient number of participants. The Client will be notified by telephone at least 2 weeks before the session was due to begin. The cancellation will be confirmed in writing. The payments received will be fully refunded. No compensation on behalf of IFP Training will be given to the Client due to cancellation or postponement of a session.

4.2 Modification of services

Any modification of the training services requires an amendment to the Training Order.

IFP Training must be given prior written notification of any change of the number of session participants, such changes being subject to the following conditions:

- Any downward adjustment of the number of the Client’s session participants can be considered by IFP Training as a partial cancellation of the session in question and will thereby be managed according to the rules listed in article 4.1 (i) that will be applied to the unit cost per participant indicated in the commercial proposal (or, failing that, by dividing the total Training Order amount by the number of Client’s participants).
- Any additional participant will be subject to prior approval of IFP Training and to an additional commercial proposal.
- Any request for a change of the number of participants must be submitted to IFP Training no later than one (1) week before the concerned session date.

Client can replace a participant with another, after notifying IFP Training.

5. Conditions for performance of the services

To fulfill the Training Order, IFP Training will perform the services proposed at the commercial proposal accepted by Client through qualified trainers.

► Performance site:

The site where the training services will be performed is indicated in the Training Order. Should the training be provided outside of an IFP Training site, the Client will ensure the access of IFP Training and its trainers to the premises where the sessions will be held, and will provide them with all material and equipment (i.e. computer, projector, screen…) needed for the performance of the services on the site in accordance with IFP Training specifications.

► Client’s information required for the performance of the services:

Client will provide IFP Training with the information and data specified in IFP Training commercial proposal, as well as all information needed to facilitate the services’ performance.

In case of late delivery of said needed information, IFP Training may decide to defer the concerned sessions and shall so inform the Client. In this case, IFP Training and the Client will jointly agree on new dates for these sessions.

All data and information provided by the Client will be kept confidential by IFP Training. At the Client’s written request, such data and information can be returned to the latter at the end of the Training Order.

The Client bears sole responsibility for the data and information that it provides to IFP Training for the performance of services. The data and information provided by the Client remain its property.
General Terms of Sale

6. Information technology and freedoms
Information of a personal nature provided by the Client to IFP Training for the performance of the session may be communicated to the contractual partners of IFP Training and to the trainers for the purposes of the services. Pursuant to the provisions of French law No. 78-17 of January 6th 1978, the persons in question can at any time exercise their rights to access, oppose and rectify said information within the IFP Training files.

7. Property rights to the pedagogical documents
Parties shall be bound by an obligation of confidentiality with regard to all documents and information specified as confidential during the training session, whatever their format. The Parties undertake to ensure compliance with this obligation by all their personnel and, more generally, by any person put in contact with the other Party by one Party during the training session.

All educational documents and information transmitted by a Party within the framework of the training sessions belong to the said Party and/or its contractual partners and/or trainers and their use, disclosure or copy is prohibited unless prior written agreement has been obtained from the disclosing Party.

Under no circumstances may these GTS be interpreted as conferring, expressly or implicitly, on the recipient Party the grant of a license right, or a promise to grant a license right, for any direct or indirect reproduction, adaptation, modification, representation or dissemination by the recipient Party, in any form whatsoever, of all or part of the documents (in particular educational documents produced by IFP Training) transmitted by the disclosing Party and/or the information contained, to its non-participants at the session or to third parties; any use for the purpose of marketing, organizing or carrying out training activities (including internal training) is expressly prohibited.

The Recipient Party is responsible for any unauthorized use, copying or distribution of information or documents (in particular educational documents produced by IFP Training) transmitted by the disclosing Party and/or the information contained, to its non-participants at the session or to third parties; any use for the purpose of marketing, organizing or carrying out training activities (including internal training) is expressly prohibited.

The Party having invoked the Force Majeure event shall:
- inform the other Party/(ies) in writing of its termination.
- inform the other Party/(ies) in writing of its termination.

The suspended obligations shall be executed again as soon as the Force Majeure event has ceased. The contractual deadlines shall be extended by the duration of said event. Should the effects of the Force Majeure event continue beyond a thirty (30) working days period from its occurrence, the Parties shall seek to reach agreement in order to decide on the further course of action for the execution of the Training Order.

In case of a Force Majeure occurrence lasting more than thirty (30) consecutive days, the Party faced with such Force Majeure occurrence can immediately terminate, by the dispatching of registered letter with an acknowledgement of receipt, the Training Order, without compensation to the other Party.

11. Termination
The Training Order may be terminated by either of the Parties in the event of non-performance by the other Party of one or more of its obligations in accordance with the Training Order. Termination shall only become effective one (1) months after the dispatching by the Party claiming non-performance of a registered letter with acknowledgement of receipt unless the breaching Party has cured its non-performance.

12. Liability - Insurance
Except in case of willful misconduct, IFP Training and the Client will respectively deal with the consequences of accidents that may occur during the performance of the Training Order and involving their own personnel, including the session participants that they directly or indirectly employ as well as their property or any property in their custody, irrespective of the author of the damages.

Accordingly, each party waives any recourse against the other for any damages caused to persons and property, except in case of willful misconduct.

Each Party shall be solely liable for any loss, damage or injury to third parties resulting from the performance of the said Party’s obligations by it or on its behalf under the Training Order. Moreover, under no circumstances can IFP Training be held liable for any financial, commercial or other damage directly or indirectly caused by the use of any information provided by IFP Training within the framework of the training sessions.
General Terms of Sale

In all other cases, Client acknowledges that the liability of IFP Training is strictly limited, for direct damages, to the price of the Training Order and excludes any indirect damages.

In view of the above provisions, IFP Training and the Client shall ensure that their respective insurers waive any subrogation rights against the Parties. Should IFP Training or Client fail to ensure this waiver, the defaulting party will bear the financial consequences.

Client undertakes to obtain and maintain, for the duration of the session and at its own expenses, the validity of all insurance policies needed in order to cover the risks, liabilities, direct or indirect damages and illnesses that could be suffered by the participant(s), its personnel or its property, obtained from duly solvent insurance companies.

At its expenses, IFP Training undertakes to subscribe and maintain the validity of the insurance needed for the coverage of its liabilities under the Training Order.

13. Personal data
As the person responsible for processing its personnel file, the Customer undertakes to inform each employee (hereinafter referred to as the User) that:
- personal data concerning him/her are collected and processed by IFP Training for the purposes of conducting and monitoring training and prospecting and promotion;
- the connection, the training path and the follow-up of the Users’ knowledge are data accessible to its services and in particular to the staff;
- in accordance with the provisions of the French Data Protection Act of 6 January 1978 in its version in force at the time of the Order, as well as the provisions of the General Data Protection Regulation (EU Regulation 2016/679 of the European Parliament and of the Council of 27 April 2016 applicable as from 25 May 2018), the User has a right to access, modify, rectify and delete his personal data (hereinafter “Rights”) concerning him and that for this purpose, an online request specifying the identity and e-mail address of the applicant can be addressed to IFP Training.

The Rights provided for in the preceding paragraph may be exercised by contacting customer service at the following email address: rgpd@ifptraining.com or by writing to IFP Training Service Marketing 232 avenue Napoléon Bonaparte, 92852 Rueil-Malmaison Cedex - France.

For all matters relating to the Order, the Parties state and guarantee that they do not and will not give or offer to give, directly or indirectly, any sum of money or any other pecuniary or non-pecuniary benefit to anyone for the purpose of obtaining the Order or facilitating its execution.

The Parties undertake to keep all accounting documents and other evidence of payments made or received and expenses incurred by them in connection with the Order during its term and at least three (3) years from the date of expiry or termination of the Order. Each Party or a third party appointed by it shall have the opportunity to audit such documents, subject to reasonable notice to ensure compliance by the other Party with the provisions of this clause.

In case of violation of this clause by one of the Parties, the other Party reserves the right to suspend, for a period not exceeding three (3) months; and/or terminate the Order automatically, without any formality, and at the sole discretion of the said Party.

14. Miscellaneous provisions - Litigation
14.1 The fact that a Party does not invoke the benefit of a clause of the Order does not entail a waiver by it of the benefit of that clause.

If one or more of the provisions hereof were to prove null and void under an applicable law or decree or a final judicial decision, it (they) would then be deemed unwritten. However, the other provisions would remain in full force and effect.

A notification by registered letter with acknowledgement of receipt shall be deemed to have been sent on the date appearing on the stamp affixed by the postal services.

Upon completion of the training session and/or in the event of early termination of the Order for any reason whatsoever, the provisions of Articles 6, 7, 8, 12 and 13 shall remain in effect.

The present General Terms of Sale are subject to French law. Any dispute, not resolved amicably between the Parties within one (1) month, and relating to the validity, performance or interpretation of these General Terms of Sale shall be subject to the jurisdiction of the Commercial Court of Nanterre, including in cases of multiple defendants.

14.2 Fight against corruption
IFP Training and the Client undertake to fight against corruption in all its forms, public or private, active or passive both vis-à-vis their suppliers or subcontractors and vis-à-vis their principals.

In this respect, the Client undertakes to comply with French anti-corruption legislation, similar legislation applicable at the place of execution of the Order when all or part of the Order is carried out outside France, as well as IFP Training’s charter of good conduct, which can be accessed on its website at the following address: www.ifptraining.com.

For all matters relating to the Client, the Parties state and guarantee that they do not and will not give or offer to give, directly or indirectly, any sum of money or any other pecuniary or non-pecuniary benefit to anyone for the purpose of obtaining the Order or facilitating its execution.

The Parties undertake to keep all accounting documents and other evidence of payments made or received and expenses incurred by them in connection with the Order during its term and at least three (3) years from the date of expiry or termination of the Order. Each Party or a third party appointed by it shall have the opportunity to audit such documents, subject to reasonable notice to ensure compliance by the other Party with the provisions of this clause.

In case of violation of this clause by one of the Parties, the other Party reserves the right to terminate the Order automatically, without any formality, and at the sole discretion of the said Party.