

**ENEA**

ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGY  
ENERGY AND THE ENVIRONMENT

# LABORATORIES FOR TESTING ELECTRIC AND HYBRID VEHICLES



## LABORATORIES FOR TESTING ELECTRIC AND HYBRID VEHICLES



The Traction Systems Test Laboratory

The Vehicles Test Laboratory

ENEA has been engaged since the early 1980s in research and development activities aimed at reducing energy use and environmental impact in the transportation sector. One of the programs in this area - conducted by the Advanced Energy Technologies Division of ENEA's Energy Department in collaboration with Italian industry and research institutions - concerns the development of innovative vehicles, in particular electric and hybrid vehicles.

*An essential part of this program involves testing and assessing vehicle technologies in the laboratory and on the road. The complex of testing facilities created at ENEA for this purpose under a program agreement with the Industry Ministry is unique in Europe. Together with road tests, these*



facilities meet all the requirements for testing components, subsystems and whole vehicles. The Battery Test Laboratory has been used for years to conduct characterisation activities for the major European manufacturers.

Two recent additions to the complex are a dynamometer that simulates driving conditions, and a traction system test station that makes it possible to characterise all the subsystems, independently or all together, in various configurations.

## LABORATORIES FOR TESTING ELECTRIC AND HYBRID VEHICLES

### AIMS OF THE LABORATORIES

Up to now the experimental and engineering approach used in developing innovative vehicles, in particular electric and hybrid vehicles, has been based on fitting new components into the structures of vehicles designed and built for the i.c.e. (internal combustion engine) market.

To the contrary, the design of an innovative vehicle requires a systemic approach that entails testing the performance of the major subsystems (electric traction engine, transmission, control logics, generator, battery, etc.) individually and as a whole.

In the ENEA testing program, this work of characterisation and verification is performed by gradually increasing the variables and phenomena involved so as to reveal the strengths and weaknesses of each of the technologies and indicate how they can be improved.

The facilities and the program set up at ENEA make it possible to run a whole series of interrelated tests ranging from those performed on individual components in the laboratory to whole-vehicle tests on the dynamometer and on the road.

The laboratories operating

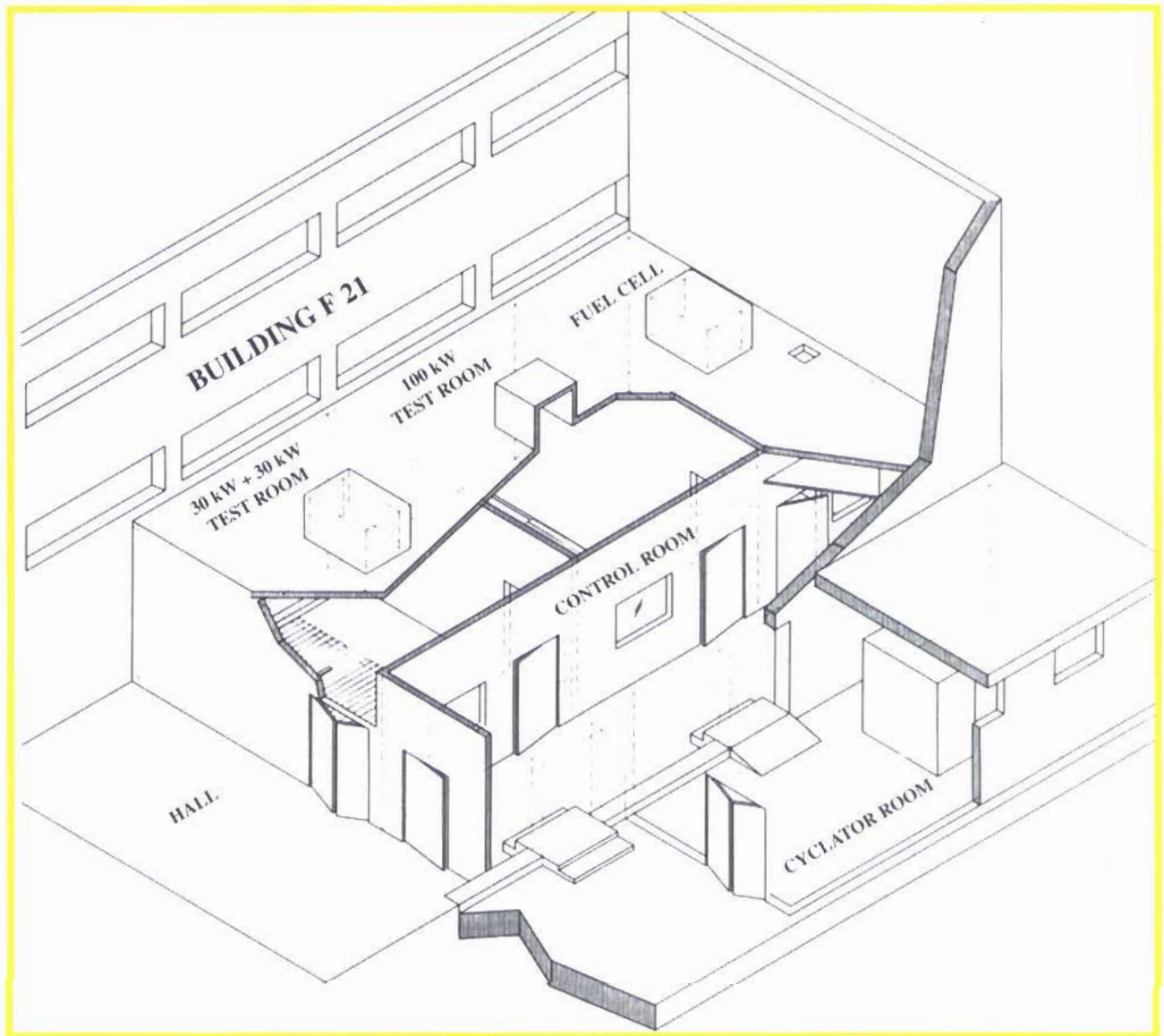


Control room; twin 30 kW brakes

at ENEA, some of which are already being used in a number of European Union programs, thus represent a suitable "tool" available to Italian and international vehicle and component manufacturers as support for the design and development of innovative vehicle prototypes.

The facilities are also available to public and private end users (local government agencies, transport companies, etc.) interested in characterising new vehicles and systems, especially as regards energy consumption and emissions, before making procurement choices.

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Lay-out of the test hall for motors, batteries and generators

## LABORATORIES FOR TESTING ELECTRIC AND HYBRID VEHICLES

### THE TRACTION SYSTEM TEST FACILITY

This facility comprises several different units, each devoted to testing one of the various traction subsystems: electricity generation systems, energy storage and management systems, traction engines and their control systems.

The units are integrated and centrally managed from a single control room that enables them to operate either simultaneously

or independently, in the case of partial tests.

A data acquisition system measures and records the parameters needed to characterise the components and systems being tested. At present the facility can test vehicles up to 6 metres long. In the future, however, the power of the largest motor brake (max. 150 kW) and

increases in the battery test unit's fuel storage potential and equipment (extension of the maximum package voltage to 600 V) will make it possible to test vehicles up to 12 metres long.

The facility is also equipped with adequate instruments for testing emissions from petrol and diesel vehicles.



Six-metre-long hybrid mini-bus manufactured by ALTRA

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### SUBSECTIONS OF THE TRACTION SYSTEM TEST FACILITY

#### Generation systems

This unit performs tests and characterisations of various types of generation systems for hybrid vehicles that use i.c. and gas turbine engines rated up to 30 kVA and fuel cells rated up to 30 kW. It is fitted with liquid and gaseous fuel feedlines (providing diesel fuel, petrol, methanol, natural gas and hydrogen), electric power mains, exhaust gas offtake, and a cooling system.



Generator test room (fuel cells, motor generators, etc.)

#### Energy storage and management systems

This unit is equipped with a thermal chamber used to test batteries under controlled conditions, and two-way AC/DC converters used both to charge the batteries and to drain them to a predetermined D.O.D. (depth of discharge) without using the components (engines and fuel cells) being tested. The converters also drive test engines when they are not connected directly to the batteries, and charge the power generator or the machine being used as a generator (braking simulations).

Battery test room



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### Engines

This unit tests conventional and hybrid i.c. engines powered by liquid or gaseous fuel (including hydrogen), and conventional and hybrid AC or DC electric engines, complete with their input systems. Housed in two separate rooms, it is equipped with one test line consisting of an asynchronous machine (and related electronics) with rated power of 120 kW (8500 rpm) and peak power of 150 kW, capable of operating on four quadrants; and a second test line consisting of two DC machines (and related electronics) that can be used together or separately to simulate the two driving wheels (engine-wheel tests and electronic differential tests).



120 kW motor test room



30 kW motor test room

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Dynamometer control room

### VEHICLE TEST FACILITY

#### The dynamometer

This facility is used to test the performance, energy consumption and emissions of vehicles rated up to 150 kW and weighing up to 4.2 metric tons, whatever the type of engine. Appropriate instruments make it possible to reproduce the vehicle's behaviour on the road. The dynamometer's high degree of programmability and automation also enable repetitive and time-consuming tests (lifetime, reliability, etc.) to be performed automatically. Thanks to its safety features, the test bed can accommodate electric vehicles, hybrids, and those powered by fuel cells or i.c. engines running on liquid or gaseous fuels (including hydrogen).

Dynamometer internal view



The dynamometer has two rollers and can test both forward- and rear-drive vehicles. It consists essentially of a DC drive system with rated power of 100 kW and peak power of 150 kW, operating on four quadrants, that returns energy dissipated by the vehicle to the grid. The peak test speed is 160 km/h.

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The test bed can simulate various operating conditions, including behaviour on the road (by altering the resistant force according to speed), braking with energy recovery, and driving cycles of any profile and duration. The cycles can be run with a person in the driver's seat (who can follow the driving profiles on a computerised display) or, if the test does not require shifting gears, by manual or fully automatic remote control from the command console, via the accelerator and brake actuators.

The facility can test the following types of vehicle:

- battery-powered;
- hybrid, where the primary generator is an i.c.e., or a fuel cell, or some other type, and the traction motor is electric;
- i.c.e. running on either liquid fuel (petrol or diesel) or gaseous fuel (natural gas or hydrogen).

Besides vehicle characterisation tests, this facility can perform specific energy consumption and emissions tests.

The facility is equipped with instruments for measuring mechanical characteristics and fuel consumption, and with devices designed specifically for testing electric vehicles:

- precision torque meter calibrated on the dynamo shaft
- encoder used in metering r.p.m.
- tachymetric dynamo used to control the actuators
- fuel and power meters
- temperature and pressure gauges
- total and partial voltage meters
- exhaust pollutant meters.

Measurements are instantly recorded, displayed on dedicated monitors, and processed online by sophisticated software for the management of configurable virtual instruments.



Electric car being tested

## LABORATORIES FOR TESTING ELECTRIC AND HYBRID VEHICLES



Electric and hybrid vehicle on testing

### The experimental fleet

The electric vehicles used by ENEA in experimental activities are fitted with various types of batteries and data acquisition systems. ENEA-developed test procedures also enable batteries, other components and complete vehicles to be characterised from the standpoint of ageing. A test circuit at ENEA's Casaccia Research Centre has been identified and characterised for this purpose, and the relevant test procedure

has been defined as an intermediate step between dynamometer tests and road tests. It enables better preliminary characterisation of the vehicle because it operates in the environmental conditions typical of normal use, but with the repetitiveness and reliability of laboratory and road tests. The test reproduces a set of parameters used in the laboratory tests, including the speed and power distribution

histogram, parking frequency and duration percentage, fuel and power consumption, etc.

### THE BATTERY TEST FACILITY

The Battery Test Facility is designed to fully characterise electrochemical storage systems used in various ways. The tests are performed on complete storage systems (rated up to 300 V and peak current of 600 A) and simulate typical operating conditions for electric vehicles (battery-powered and hybrid) and other stationary applications (photovoltaic and wind generators, load smoothing in power grids). The tests that can be performed in this laboratory make it possible not only to verify the suitability of battery performance for specific applications, but also to contribute to battery development.

The laboratory is equipped with three battery cyclers used to run various electric cycles designed to simulate the cycles specified in Italian and international standards (ECE, IEC, CENELEC, CEI), or that must meet other operating specifications (SAEJ227, ECE15, FUDS, SFUDS, TC69, DST), with voltage and current fields ranging from 48 to 310 V and from 6 to 600 A. The battery cyclers are fully programmable and controllable from a personal computer, which means that the tests can

be run automatically. Electrical performance and cyclability (lifetime) are verified by setting up charge and discharge cycles at constant or variable (step-by-step) voltage, current or power, according to predetermined and programmed profiles. The battery cyclers measure and record aggregate parameters (battery voltage and current, ambient temperature) with high precision and sampling frequency. Measurement of more parameters at higher sampling frequencies is separated from the control function in order to assure greater reliability and safety in test procedures. The use of three independent data acquisition systems makes it possible to record data on

partial voltages, battery temperature maps, and so on. To ensure the reproducibility of test conditions, safety, and adherence to the specifications required by applicable standards, the facility is also equipped with two medium-size climatic chambers (1.5 and 2.25 m<sup>3</sup>, temperature fields from -40 to +100° C) and with emission control and venting systems. Mechanical stress tests of battery modules can also be performed by means of electrodynamic shakers available at other ENEA laboratories, using a portable battery cycler.

Battery test laboratory



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ENEA is a government research and innovation organisation operating to further sustainable economic development, competitiveness, job creation, and environmental protection.

ENEA also operates on behalf of public administrations by providing advanced services in the areas of energy, environment and technological innovation.

The Agency has around 3600 employees operating in mainly multidisciplinary research centres located throughout the country.

Further information:

ENEA - Casaccia Research Centre  
Advanced Energy Technologies Division  
via Anguillarese 301  
00060 S. Maria di Galeria (Rome)  
Tel. + 39 6 30484512 - Fax + 39 6 30483795  
E-mail: [vellone@casaccia.enea.it](mailto:vellone@casaccia.enea.it)

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