

Introduction of Automotive Testing Department

Hiroshi NAKAMURA

Strongly linked with the automotive industry, the history of automotive testing business by HORIBA Group has developed itself along with innovative automotive technologies. Since the first emission measurement system developed in 1964 following the launch of automobile emission control, HORIBA Group has continued strengthening emission control and advancing the emission reduction technologies as well as developing the emission measurement techniques and technologies. In the 2000s when the computerized vehicle technologies like hybrid electric vehicles were advanced, the Group extended the scope of its business operation from emission test facilities to power train test facilities containing transmissions and E-motors, brake test facilities and wind tunnel test facilities to provide solutions for a wide range of applications including the areas of the intelligent transport system.

Introduction

In 1963, the Clean Air Act covering industrial emission sources came into effect in the United States. Further in 1970, the revised Clean Air Act, also known as the Muskie law, started full-scale regulations on hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxide (NOx) contained in automobile emission. Since then, emission regulations have been strengthened each year. For these tighter regulations, the automotive industry has carried out technical development in relation to the improved internal combustion, emission after-treatment and computer vehicle control. It was 1964 when HORIBA Group started its automotive testing business by offering the emission measuring equipment following the introduction of regulations. The measurement techniques have evolved with technical innovations of the automotive industry. In particular, the Group started providing test automation that dealt with the more complicated test facilities and procedures associated with the introduction of computer control to vehicles and controlled the overall emission test facilities, which had a significant impact on the Group's subsequent business development. In the 2000s, the computerized vehicle technologies like hybrid electric vehicles (HEV) experienced remarkable growth. Triggered by the advancement, the Group extended the scope of its conventional business operation focusing on emission test facilities to that including other automotive testing facilities. Today the Group provides solutions for a wide range of applications in the automotive development areas, such as the driveline testing including transmissions and E-motors, brake testing and wind tunnel testing. Recently, the Group has extended the areas of business to the intelligent transportation systems (ITS) and offered

digital tachographs, drive recorders and other equipment to collect operation data of running vehicles, or the integrated operation control support systems (HORIBA Fleet Linkage, HFL) in which the operation data can be handled on the crowd database. This report will look back on the history of HORIBA Group's automotive testing business strongly linked with the automotive industry and introduce the major applications.

Automobile Emission Measurement Business

Automobile emission measurement is motivated by different regulations of different nations or regions. Not only is it necessary to conduct the certification test to see whether the newly developed engines or vehicles conform to emission regulations, but the assessment of emission reduction techniques is crucial looking ahead the trends of regulations even at the R&D stages. This report will introduce some examples of emission and particulate matter measuring instruments intended for use for regulations or R&D.

Emission Measuring Instrument

As has been mentioned, HORIBA Group's first release in 1964 of the emission measuring equipment (Figure 1) in Japan was triggered by the Clean Air Act coming into effect in 1964. The Group subsequently continued developing analyzers in consideration of emission regulations. In the 1970s when the emission regulations on in use vehicles came into effect in Japan, the Group developed the instruments employing the non-dispersive infrared (NDIR) CO analyzer that has still been the basic principle of emission densitometry, total hydrocarbon (THC) analyzer based on flame ionization detection (FID) and the NO_x analyzer based on chemiluminescent detection (CLD). The instruments based on these principles were delivered to the United States Environmental Protection Agency (EPA) in 1975. Meanwhile, HORIBA Group was issued a patent for critical flow venturi (CFV), another important technology associated with emission measurement by Mirco Ford of the United States. This added to HORIBA Group's lineups the constant volume dilution and sampling equipment (CVS) used to dilute and sample the total volume of emission. The combination of the abovementioned emission analysis principles with the CVS has been inherited to date as the official method of the emission certification test.

For half a century since the introduction of emission regulations, the regulation values have become more and more stringent. For instance, the 2012 regulations were reduced by about a hundredth for CO, by about a two-hundredth for NO_x, or by a thousandth for THC, of which the tendency has continuously been strengthened. These strengthened emission regulations have led various emission reduction techniques to development and practical use. Some representative techniques for the after-treatment system include a combination of a lean burn engine with lean NO_x trap (LNT) or three-way catalyst (TWC), or a combination of a diesel engine with urea selective catalytic reduction (Urea-SCR), diesel oxidation catalyst (DOC) or diesel particulate filter (DPF). The development and evaluation of these after-treatment techniques require the measurement not only of regulated components but intermediate products generated by catalytic reaction and those components inhibiting catalytic reaction. Figure 2 shows some example measuring instruments used for catalytic evaluation. A variety of instruments

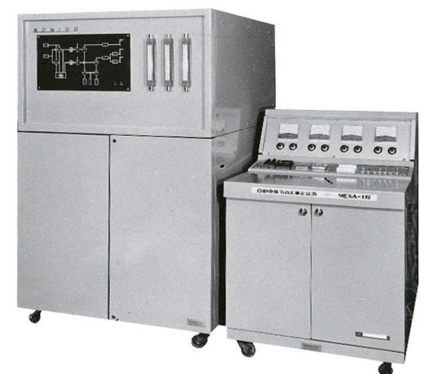


Figure 1 Japan's first emission measuring equipment (MEXA-1 type)

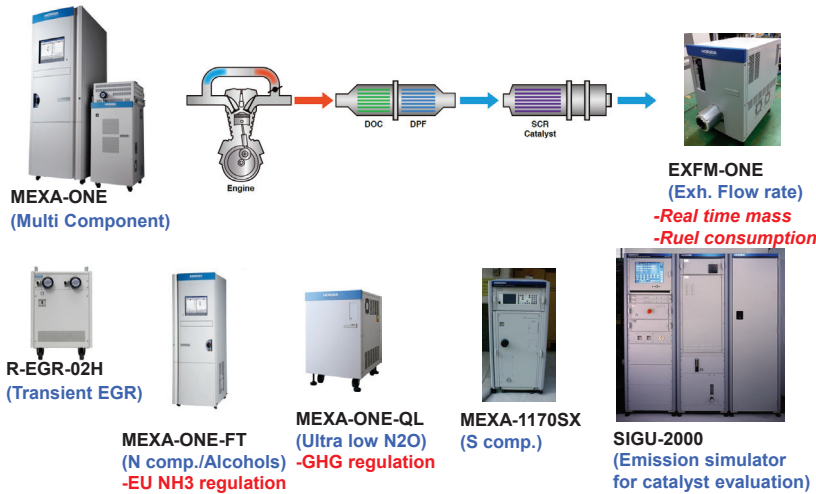


Figure 2 Emission measuring instruments lineups (examples) Source: World Car Fans.com

are lined up including MEXA-ONE, the latest model of the emission measuring equipment with the conventional analyzer, as well as the ultraviolet fluorescent S compound analyzer used to evaluate sulfur poisoning of catalyst, Fourier transformation infrared (FTIR) analyzer that allows the simultaneous measurement of nitrogen compounds and quantum cascade laser (QCL) analyzer.

Particulate Matter Measuring Instrument

Automobile emission control has set up reference values not only for gas components but for particulate matters (PM). Figure 3 shows some example particulate matter measuring instruments including the official method of PM measurement.

PM is measured by means of the “filter gravimetric method” in which similarly diluted exhaust gas is passed through the filter to weigh what is collected by the filter. With an increase in stringency of regulations on PM, the current regulation level requires PM as small in mass as 10 to 20 µg to be measured on a filter about 100 mg. This is the level in which event atmospheric humidity while weighing a filter or buoyancy imposed on the filter itself could affect the weighing. Furthermore, the amount of PM collected vary by dilution ratio or diluted exhaust gas temperature, which means the filter gravimetric method requires equipment

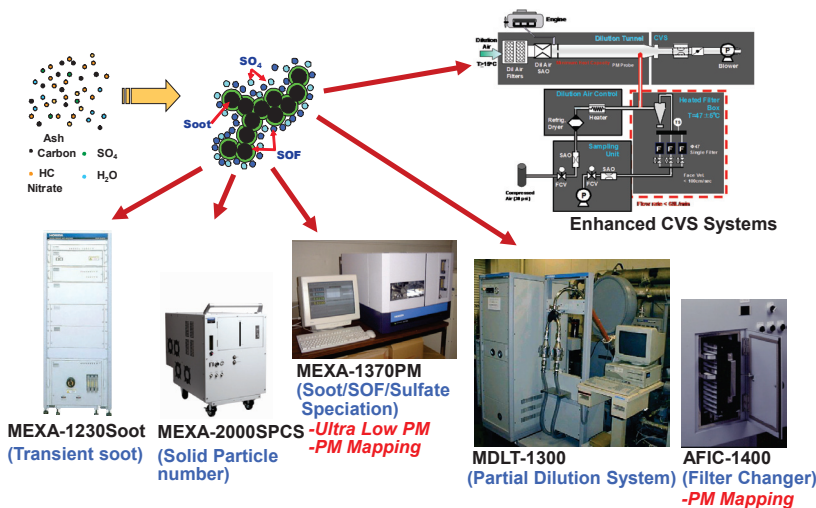


Figure 3 Example particulate matter measuring instruments Ref.: J. H. Johnson et al., SAE940233

management in a more stringent way. In Europe, the number of particulate matters began being regulated in addition to regulations by the filter gravimetric method. The regulation on the number of particulate matters uses the solid particulate measuring instrument with the condensation particle counter (CPC) as the sensing part. In the field of engine conformance or after-treatment system development, the measuring equipment for instantaneous soot emission, PM composition analyzer by the combustion method, and other instruments not by the official method of regulation are also used for the purpose of more efficient development and testing.

Onboard Emission Measuring Instrument

In the United States, the test method using the onboard emission measuring instrument was introduced in 2007 for measuring emissions from diesel in-use heavy vehicles. The similar regulation started in Europe in 2013 on the

basis of onboard measurement. In addition, the use of onboard measurement is under consideration for the certification test for small passenger vehicles. Figure 4 shows HORIBA Group’s onboard emission measuring equipment (OBS-ONE).The onboard equipment must be small, battery-driven and power efficient. This is the reason for the system configuration in which emission is measured with the exhaust gas flowmeter using a pitot tube type flowmeter as well as the exhaust gas concentration analyzer, unlike the conventional laboratory test facilities.



Figure 4 Onboard emission measuring instrument (OBS-ONE)

Test Automation Business

Automobile or engine emissions are generally measured in a dedicated laboratory except onboard measurement. The laboratory is equipped not only with the emission measuring equipment or sampling equipment but various other equipment used to drive vehicles and engines. This section will explore the test automation that controls all these facilities as a single system to carry out emission tests.

Automated Vehicle Emission Test

In 1977, HORIBA Group partially acquired a US company Inter-Automation to strengthen software development capabilities. Having offered the hardware only including the emission measuring equipment and its peripheral equipment before the acquisition, the Group extended the scope of its business to the development of test automation that allowed automatic control of the overall emission measurement system and test processes. The extension was intended for the system to offer the total solution for emission measurement in the context of more complicated demands for facilities. Figure 5 shows example emission test facilities for vehicle testing. What is applicable to test automation is the Vehicle Emission Test System (VETS), an application of the automobile emission test. VETS allows automatic control of emission measuring instruments (MEXA/CVS), chassis dynamometers (VULCAN) or automatic driving robot (ADS). It further automates the legally required processes of the emission test including vehicle/test item settings, calibrations of facilities and preparations for the tests, and offers the data analysis tool or the function to output test results, contributing to a significant reduction in test man-hours.

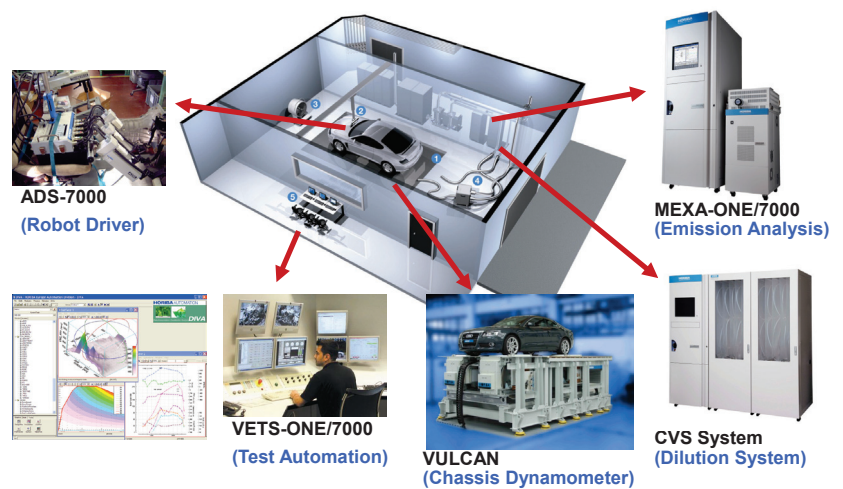


Figure 5 Example automobile emission test facilities

Automated Engine Emission Tests

In 2001, HORIBA Group established a joint corporation specializing in test automation with Ricardo from the UK and Schenck Pegasus from Germany to strengthen software development functions in a global context. This establishment was achieved in response to demands for global sharing of development processes and data in association with global reorganization of

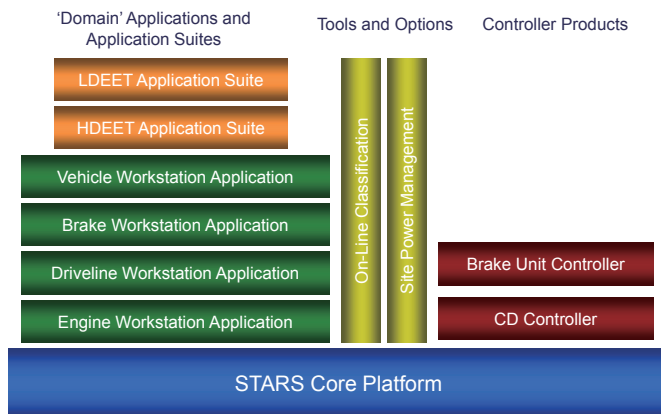


Figure 6 STARS platform configuration

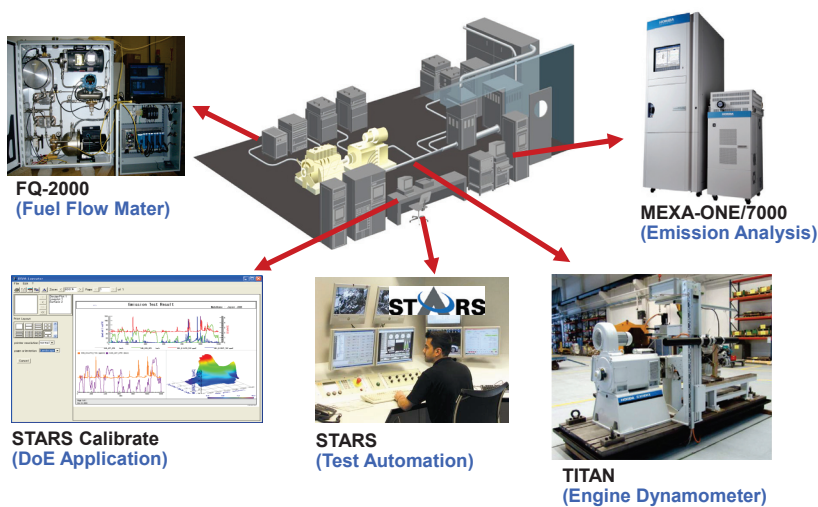


Figure 7 Engine emission test facilities (example)

the automotive industry after the year 2000. Figure 6 shows the configuration of STARS, a global platform of HORIBA Group’s test automation. The STARS platform supports a wide range of test applications and allows test engineers to flexibly change test configurations. Moreover, the “cluster (distributed test cell)” configuration that constitutes architecture by service covers the facilities of various different scales from a single test bench to test cells of the complex equipment. With the work stations appropriate for such tests as the engine, driveline, brake or vehicle tests, STARS can add user interfaces or functions according to individual test facilities. In contrast, STARS shares the basic services and data structure and thus allows the data on test results or configuration to be shared by multiple test facilities. It also provides a prepackaged application suite to those tests requiring complicated procedures. For example, an application suite HDEET for the heavy diesel engine emission test integrates the execution, analysis and report functions and offers the available test set. It allows further advance customization as well. Figure 7 shows an example package of the engine emission test facilities. The application designed for the engine

calibration test requires a function for optimizing experimental man-hours that tend to be enormous due to an increase in test parameters. STARS optimizes the conformance processes by combining STARS Calibrate, the Design of Experiment (DOE) tool.

Mechatronics Business

When entering the 2000s, the technologies for motorized automobiles started developing and spreading rapidly. In the context of the trend, HORIBA Group acquired the automotive testing device business from Carl Schenck in October 2005. This extended the scope of the Group’s business from the conventional emission test facilities to the driveline test facilities, brake test facilities and wind tunnel test facilities (Figure 8). One could argue the Group is now ready for providing a wide range of solutions for overall automotive R&D tests. The following sections will introduce an overview of these test facilities.

Driveline Test Facilities

The driveline test facilities are intended for various driveline components including transmissions, clutches, torque converters, axles, or E-Motors required for HEVs. As the test facilities simulate the actual load applied when a finished car runs, the input shaft replicates power from the engine while the

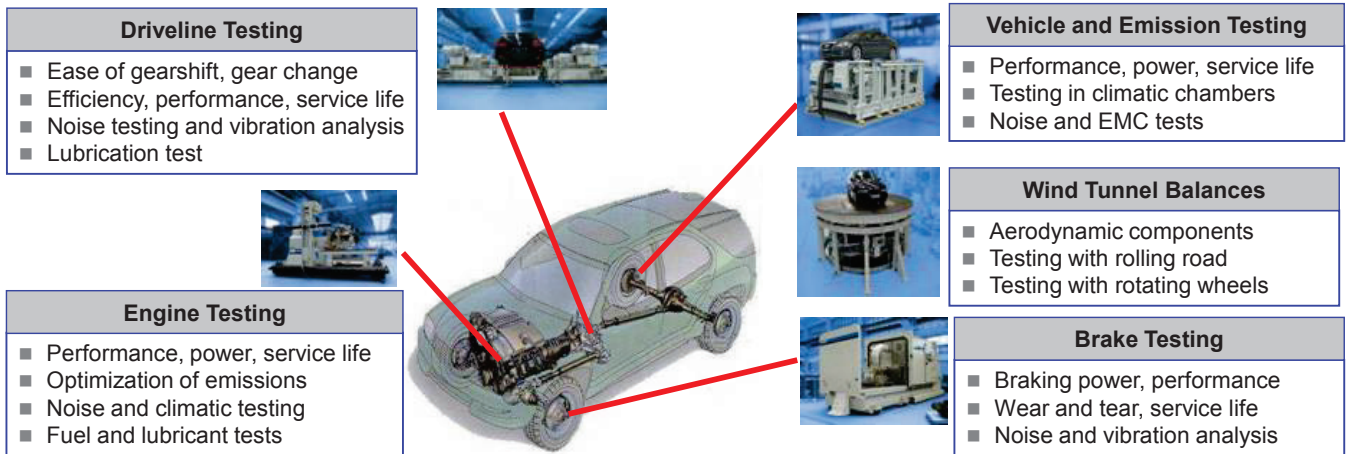


Figure 8 HORIBA Group's automotive test facilities

output shaft replicates load on tires. Here, the facilities can evaluate multiple engine models without changing hardware connection if changing the settings of the engine model to be simulated. Further, they can be combined with the engine torque pulse simulation (ETPS) that replicates the cyclic variation of the combustion engine torque by the use of the ultra-low inertia dynamo for input. The use of these functions allows component tests to be carried out ahead of schedule even before the actual engines or vehicles are finished, contributing to a shorter period for vehicle R&D.

Brake Test Facilities

The brake test facilities are used for the evaluation tests for quality assurance and technological improvement of brakes, one of the most important safety mechanisms of a vehicle. The tests include the friction coefficient test or abrasion tolerance test on brake friction materials, as well as the performance tests on the brake alone. In addition, the NVH (noise, vibration and harshness) test is carried out for the package including not only the brake module consisting of the actually used rotor disk, brake pad and caliper but the suspension and axle assembly.

Wind Tunnel Test Facilities

The wind tunnel test facilities (Figure 9) are used to optimize vehicle aerodynamic force. In the wind test, a vehicle is placed on the measurement platform of a wind tunnel balance to accurately measure the tridirectional forces and moments generated by airflow. To make airflow under the vehicle and around wheels closer to the actual airflow, a wheel spinner belt that rotates wheels in synchronization with wind speed could be placed on the balance.



Figure 9 Wind tunnel balance (example)



Figure 10 Integrated operation management system (HORIBA FLEET LINKAGE)

ITS Business

HORIBA Group’s ITS business began with the provision of digital tachographs in 1983 for the purpose of truck operation management. Subsequently in 2005, the Group developed and started selling drive recorders, an onboard unit that records images at the time of an accident or near accident as well as traveling data and manages safe operation. The Group has already sold 10 thousand recorders. The Group has also started providing the “integrated operation management support system: HORIBA FLEETLINKAGE (Figure 10)” service that compiles operation data of the onboard unit in the network server and provide analysis and services. Compiling the enormous amount of data by means of the Internet-based cloud computing facilitates information browsing or the preparation of data analysis result forms on the Internet. Of course users do not have to manage the data. The technology helps optimize business incorporating improved fuel efficiency by safe or economical drive as well as vehicle location information and business information particularly in the transportation industry where a number of vehicles are owned.

Conclusion

Currently, HORIBA Group is based in 43 locations of 26 different countries globally. In the Group, not only do the major locations carry out production and development of such core technologies as emission measurement technology, control technology and simulation technology, but each location has the engineering function to flexibly cope with demands from each region (Figure 11). For the purpose of optimizing the test facilities in conformity to the development processes varying by facility users, the Group also owns test facilities globally and makes up the environment to conduct tests with users.

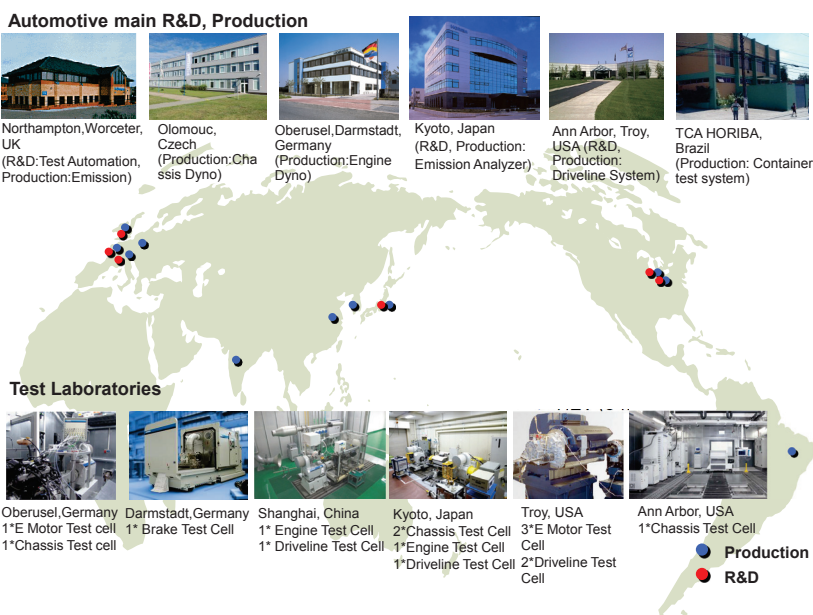


Figure 11 Major development and production locations for HORIBA Group’s automotive testing business

Looking back on the history of HORIBA Group, the Group has continuously developed its test facilities together with customers in accordance with the advancement of automotive technologies. To “provide customers with solutions”, the Group would like to build the OPEN & CUSTOM Test System that incorporates new technologies (OPEN) and flexibly copes with various demands (CUSTOM), and make continuous contributions to part of the automotive industry development.

**Hiroshi NAKAMURA**

Automotive Segment Strategy Chief manager
Corporate & Segment Strategy Division
HORIBA, Ltd.
Ph. D