Review

Automotive Development and Progress in HORIBA's Emission Measurement Technologies

Hiroshi Kawamura

The progress in HORIBA's emissions measurement systems has been closely connected to trends in vehicle development. Innovations in automotive technology, stemming from emission regulations and implementation of computer control systems, have especially had great influence on analytical technologies. With the advent of emission regulations, HORIBA developed its first automotive emission analyzer, MEXA-1 and constant volume sampler (CVS), in 1964. Ever since, HORIBA has constantly enhanced its devices to accommodate the most recent requirements, such as increased precision to match stricter emission regulations and advanced automation for improved efficiency of increasingly complex testing. The current model, MEXA-7000 Version 3, built on over forty years of emission analyzer development enables emission analysis of the latest Super Ultra Low Emission Vehicles (SULEV).

Introduction

Measurements made on automobiles are wide-ranging, from physical properties such as mass, size and torque, to chemical properties such as emission gas composition and sensory evaluations such as ride quality, noise and vibrations. Ever since HORIBA expanded its core technology applying infrared absorption to emission measurement in 1964, the manufacture and sales of automotive measurement systems have become one of our main business domains. Needless to say, such progress in automotive measurement systems has been closely connected to trends in vehicle development. Improvements to engines and catalysts following the strengthening of emission regulations, as well as the increasing complexity of development testing with the implementation of computer control systems have played an especially strong role. This report traces back the history of HORIBA's MEXA series of products related to emissions measurement and their correlations with the automotive industry.

Overview of Automotive Emission Measurement

Automotive Industry and Emission Measurement

Along with convenience, the need for automobiles is rooted in the intrinsic human desire for locomotion. The current prosperity of the automotive industry is the result of promoting continued technological development to meet this need and releasing new, high-quality products on a timely basis. Although over the years, the industry

has faced various global issues such as pollution control and oil crises. But instead of viewing these issues as negative, they were used as opportunities, and as springboards for technological innovations such as the development of advanced engines and after treatment devices.

HORIBA's emission measurement systems have evolved and grown alongside such developments in the automotive industry. The advent and strengthening of emission regulations has had a vast impact on the emergence of analytical technology. Historically, the promulgation of the 1970 Clean Air Act in the United States greatly influenced trends in emission regulations. The Clean Air Act clearly stipulated that HC and CO emissions from vehicles will be regulated from 1975 onwards. Eyeing the enforcement of emission mass regulations, HORIBA put into practical use its two core technologies: the MEXA series of gas analyzers and the constant volume sampler (CVS) which samples exhaust gases for analysis. These technologies were the start of the emission measurement system still used today. Ever since the Act's implementation in 1978, emission standards for new vehicles have repeatedly been strengthened, but up until now, there have been no major changes to the basic emission measurement framework of "CVS + automotive emission analyzers."

Characteristics of Automotive Emission Measurement

Emissions from vehicles and engines have the following physical/chemical characteristics:

- A mixed flow of gases, liquid droplets and solid particles
- Temperature variations from room temperature to 700°C or higher
- Composition changes according to the state of engine operation

Such characteristics of emissions are quite troublesome for measurement purposes, so automotive emission analyzers require measurement technologies that can quantify target components, as well as sampling technologies that can introduce emissions to the detector without altering their properties.

The sampling methods currently used in emission analysis are classified as follows:

- Batch measurement : A method of sampling target gases into bags, and measuring concentration by introducing the gases from the bags into analyzers after completion of testing
- Continuous measurement : A method of introducing target gases continuously into the analyzer and measuring temporal changes

A typical example of batch measurement is CVS technique used for mass emission measurements according to emission regulations (new vehicle certifications) where specifications for basic performances are stipulated by law. On the other hand, continuous measurements are often used for development of engines and catalysts. With regards to analyzers used for development purposes, the required precision, repeatability, responsiveness and other factors all differ by the intended target and purpose, so the usability of analyzers need to be carefully considered.

History of The MEXA Series

The Need for Automotive Emission Measurement and The Birth of MEXA

Figure 1 illustrates the evolution of HORIBA's MEXA series of automotive emission analyzers. When emission regulations were implemented in some countries, what was first required was an automotive emission analyzer with sufficient precision and repeatability. To meet this demand, HORIBA developed automotive emission analyzers utilizing the non-dispersive infrared (NDIR) method, the MEXA-1 in 1964 and the MEXA-13 in 1966. HORIBA also developed the MEXA-77 with a NDIR method CO/CO2 detector, a hydrogen flame ionization method THC detector (FID)

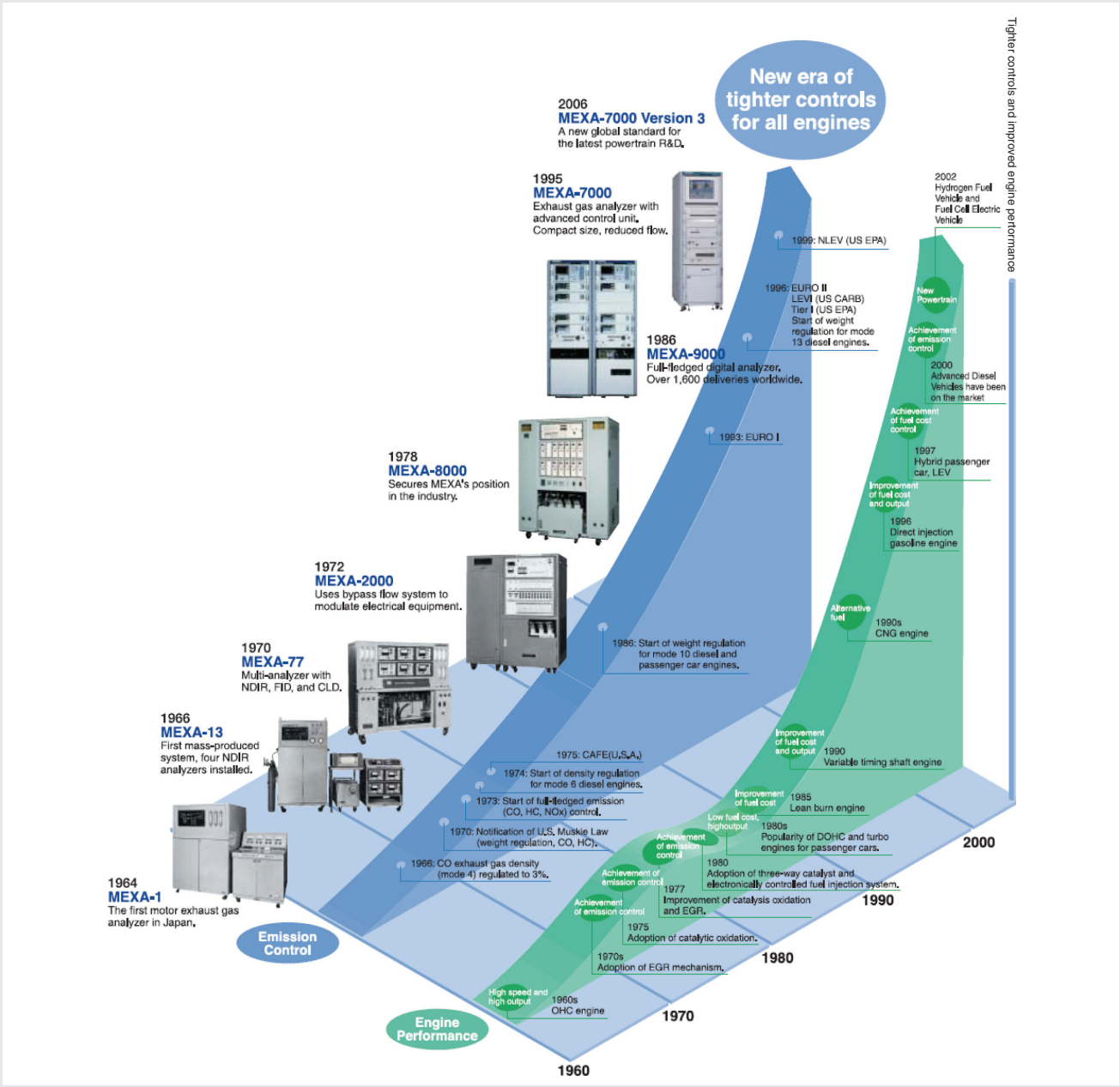

Figure 1 Evolution of Engine Technologies and HORIBA's MEXA Series

and a chemi-luminescence method NOx detector (CLD) in 1970, and the MEXA-2000 with improved analyzer sensitivity and unitization in 1972. So the MEXA series have been developed to meet market demands and provide high-quality products since the beginning of development. One of the achievements has been the adoption of MEXA by the U.S. Environmental Protection Agency (EPA), which provided a springboard for HORIBA's overseas deployment of products related to automotive emission analysis.

Securing the Position of Automotive Emission Analyzers

As stated earlier, regulations were gradually strengthened, i.e. emission concentration levels were lowered during the 1970's and thereafter, in efforts to cut pollution levels that were not improving. As a result, automotive emission analyzers with higher sensitivity and reliability were required, and HORIBA answered with the release of the MEXA-8000 in 1978. The MEXA-8000 furthered efforts toward unitization and enabled the measurement of up to 14 components. The MEXA-8000, the basis for the current MEXA series, has been popular in both Japan and other countries, and provided a foothold on which HORIBA products became industry standards.

Efforts towards Digitalization

Emission regulations were one of the motivating factors in the commercial application of the electronically-controlled fuel injection system, a technology that provides precise control of the engine. This meant that, with the need to optimize fuel injection control systems during vehicle development, testing became more complex than ever before, and with regards to emission analysis, the demand for improved testing efficiency and enhancement of functionalities steadily increased. It was under these circumstances that HORIBA released the MEXA-9000 series in 1986, under the conceptual keyword of "digitalization." At the same time, a data processor (host computer) to communicate with the MEXA-9000 was developed, enabling the operation of laboratories online, data extraction, and the creation of ledgers. This in turn enabled the unified operation of increasingly diversifying measurement equipments and improved the functionality of the system. HORIBA took this opportunity to shift its emphasis from providing individual units to providing entire systems; this was the impetus in which HORIBA set its current goal of becoming a Solution Provider that offers systemization of measuring equipments and solutions that improves the efficiency of various development/testing tasks.

Super Ultra Low Emission Measurement

During this last decade, automotive emission limits has been lowered considerably, to 1/100th of the level during the 1970's for CO and NOx, and less than or equal to 1/1000th of the same level for HC. This indicates the high levels of technological innovations the automotive industry managed to accomplish in a short period of time. During this period, HORIBA has consistently supported these technological innovations from the aspect of automotive emission measurement. With regards to the MEXA series lineup, the first model of current MEXA-7000 was released as

Version 1 in 1995. The current methods of measuring emissions gases follow the ones established in 1970, but the series realizes high sensitivity and precision as well as faster response.

The MEXA-7000 has been continuously upgraded from Version 2 to Version 3, and meets the demands of the latest emission regulations. With regards to the CVS, which are combined with MEXA products, HC contamination (a cause for measurement errors) has been minimized by reducing the potential area of the gaseous contact and through careful selection of the materials. Also, through the optimization of low emission measurements, the CVS-MEXA system can accommodate emission measurements for Super Ultra Low Emission Vehicles (SULEV).

Test Cells for Emission Analysis

To actually measure emissions from vehicles or engines, various equipments other than the CVS and MEXA are used. Especially regarding facilities for emission regulations, the criteria of various details vary according to factors such as the purpose of the vehicle/engine, fuel (gasoline, light diesel oil), vehicle mass and engine output. Criteria also differ for the regulating country/region and the phase of the regulation, so equipments that match the requirements of the specific regulation are required. Figure 2 is an example of the latest vehicle emission testing facility. To perform a vehicle emission test, a special test room (test cell) and a chassis dynamometer, a device that replicates on-road driving inside the test cell, are required. Emission gases

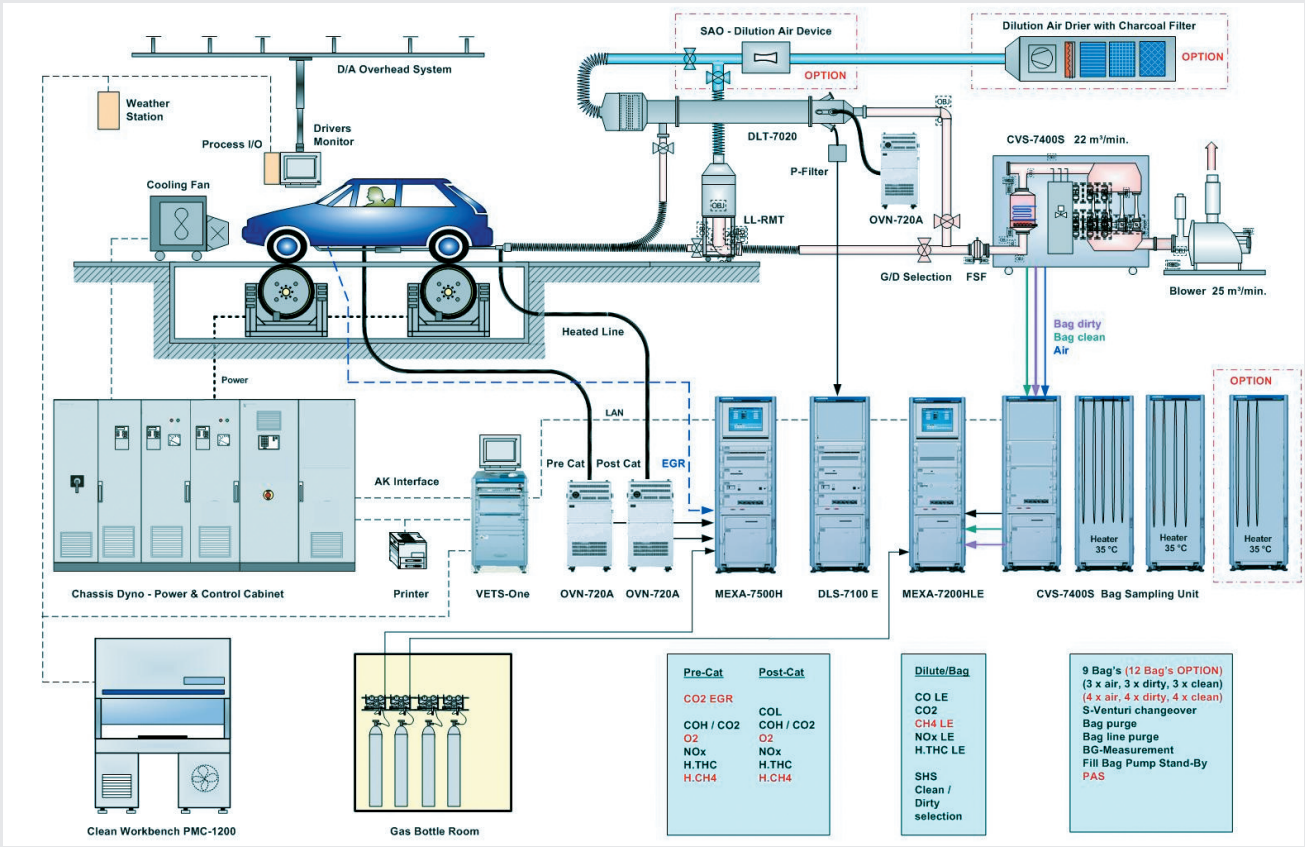

Figure 2 Latest Low-Concentration Emission Measurement Facilities

are sampled with the CVS, but for diesel vehicles, a dilution tunnel (DLT) to extract particulate matters (PM) is also added. The example in Figure 2 shows a system constructed for EU testing, accommodating both gasoline SULEVs and clean-diesel vehicles, and the use of the DLT can be switched on/off. The Vehicle Emissions Test Systems (VETS) automates the control of all equipment as well as providing data extraction. When testing the engine of a passenger vehicle by itself, a different test cell for engines is used. Such emission test cells are needed not just for emission certification testing, but also during vehicle/engine development as well.

Conclusion

This report focused on the history of automotive emission analyzers from the MEXA-1 to the MEXA-7000 series. In reality, HORIBA has developed many other equipments related to emission measurement. Focusing on the field of analyzers alone, HORIBA provides a wide range of products such as compact simple analyzers for the inspection of in-use cars, a lineup of analyzers to measure unregulated components (needed during development), on-board systems to measure emissions during on-road driving and a system providing real-time measurement of particulate matter emissions. In light of the increased ecological awareness, the automotive industry is currently engaged in the development of forward-looking technologies such as a new method of diesel emission after-treatment systems and hybrid vehicles. HORIBA will continue to provide measurement technologies to meet the new demands for measurement that will be generated from these new technologies.

Hiroshi Kawamura
HORIBA, Ltd.
Automotive Test Systems Division
General Manager