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Development of 1MW high efficiency gas engine cogeneration system

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ABSTRACT

Global warming has been accelerating due to expansion of energy consumption associated with economic development. International energy agency (IEA) said, the world's CO2 emissions from energy consumption was 306 million tons in 2010, and recorded the worst. Energy consumption and CO2 emissions are increasing steadily.

In such circumstances, natural gas cogeneration system is highly expected as a system to help suppression of global warming. This is because natural gas cogeneration produces electricity and heat from fossil fuels on-site, since to allow both energy uses at the customer side. The natural gas is a fossil fuel with the lowest CO2 emission. So the use of natural gas contributes to CO2 reduction. So, natural gas cogeneration is a system that can highly effective be used about the fossil fuel for the low carbonization.

In addition, the cogeneration that supplies electricity and heat to the customer is a system that contributes to the improvement of the energy security, for example in case of accident of nuclear power plant.

Tokyo Gas Co., Ltd. and Mitsubishi Heavy Industries, Ltd. jointly started the development of 1MW high efficiency gas engine cogeneration system by the above-mentioned background from 2007. The gas engine was adopted as the motor of the cogeneration because the gas engine cogeneration has the feature with high generation efficiency. In this development, generation efficiency of 42.5% which is top class performances in the world was achieved in the 1MW class cogeneration system due to its high power density and low engine speed. And total efficiency of 80% was achieved by improving the heat collection calorie by reviewing the heat exchanger.

In addition, the new cogeneration package was developed. The feature of the new cogeneration package is that the width is narrower than the distances between the pillar and the pillar in the building for improvement of installation into an indoor machine room. As a result, the width was set to 2500mm from a past 3000mm.

In this text, it reports on the feature of the natural gas cogeneration system and the approach of this development.

TABLE OF CONTENTS

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1. Abstract

Global warming has been accelerating due to expansion of energy consumption associated with economic development. International energy agency (IEA) said, the world's CO2 emissions from energy consumption was 306 million tons in 2010, and recorded the worst. Energy consumption and CO2 emissions are increasing steadily.

In such circumstances, natural gas cogeneration system is highly expected as a system to help suppression of global warming. This is because natural gas cogeneration produces electricity and heat from fossil fuels on-site, since to allow both energy uses at the customer side. The natural gas is a fossil fuel with the lowest CO2 emission. So the use of natural gas contributes to CO2 reduction. So, natural gas cogeneration is a system that can highly effective be used about the fossil fuel for the low carbonization.

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In this text, it reports on the feature of the natural gas cogeneration system and the approach of this development.

2. Feature of natural gas cogeneration

The natural gas cogeneration system is a system that generates electricity and heat on-site from natural gas, and supplies it. The cogeneration is composed of three (engines and turbines, the generator, and the waste heat recovery equipment). Electricity is generated by the mechanical work from the engine and turbines, and steam and the hot water are generated from the waste heat recovery equipment. Therfore, 70-80% of fuel consumption energy could be collected as electricity and heat.

Three types exist in the natural gas cogeneration, gas engine type, gas turbine type and fuel cell type. “Gas engine type” cogeneration is that gas engine drives generator and generates electricity, and also collects steam and hot water from exhaust gas and cooling water. The power generation output of gas engine cogeneration exists from 10kw to around 9MW and most gas engine cogeneration exceeds generation efficiency 40%.

“Gas turbine type” cogeneration is that gas turbine drives generator and generates electricity, and the waste energy is collected as steam from the exhaust gas boiler set up after the gas turbine. The generation efficiency is about 20-30%, lower than other type of cogeneration. But heat collection efficiency is 50-60%, higher than other type of cogeneration.

"Fuel cell type" generates electricity from the oxygen and hydrogen produced by using the reaction opposite to electrolysis of water, and collects the heat generated at the same time as steam or a hot water. “Proton-exchange membrane fuel cell” that the start stop is easy is introduced into small scale site. And introduction of high efficiency "Melted carbonate type fuel cell" is advanced in hundreds of kW class. Furthermore, development of "Solid oxide type fuel cell" that the power generation efficiency is the highest is in progress.

"Gas engine type" and "Gas turbine type" are dependable by the improvement development of the past, and the introduction results are almost occupied with two types. The customer who needs a lot of electricity selects "Gas engine type" that the power generation efficiency is high and the customer who needs a lot of heat selects "Gas turbine" that the waste heat recovery efficiency is high. The customer who needed a lot of electric powers in the power generation output 1MW class was made a target in this development. So development of making to high efficiency and high performance of gas engine cogeneration was conducted.

Table 1 Comparison of cogeneration type

Type	Gas Engine	Gas Turbine	Fuel Cell
Unit Capacity	1 - 9000 kW	30 - 100000 kW	50 - 10000 kW
Generation Efficiency	26 - 49 %	20 - 35 %	PEFC : 35 - 40% PAFC : 35 - 42% MCFC : 45- 60% SOFC : 45 - 65%
Total Efficiency	65 - 92%	70 - 80%	60 - 80%
Heat Recovery Temp.	Exhaust Gas : 400 - 600 degC Hot Water : 85 - 90 degC	Exhaust Gas : 450 - 500 degC	Operation Temp. PEFC : 100 degC PAFC : 220 degC MCFC : 700 degC SOFC : 1000 degC
Countermeasure of Exhaust Gas Emission	Lean Burn + SCR Catalyst or Three Way Catalyst	Lean Burn Water Injection SCR Catalyst	Not required
Feature	Exhaust Gas is Clean. Exhaust Gas Temp. is High.	Small and Lightweight Exhaust Gas Temp. is High. -> Easy to vapor recovery.	Generation Efficieancy is High. Vibration and Sound Noise is Low. Exhaust Gas is Clean.

Next, environmental friendliness between conventional system (system that combined thermal power plant with the boiler) and the natural gas cogeneration system was compared at the same condition. As a result, the natural gas cogeneration system has understood the conservation of energy of about 31% and CO2 of about 47% can reduce (Refer to Figure 1). So natural gas cogeneration system which generates electricity and heat on-site and enables to use energy is a system which is expected further introduced into customer from the viewpoint of the global warming prevention.

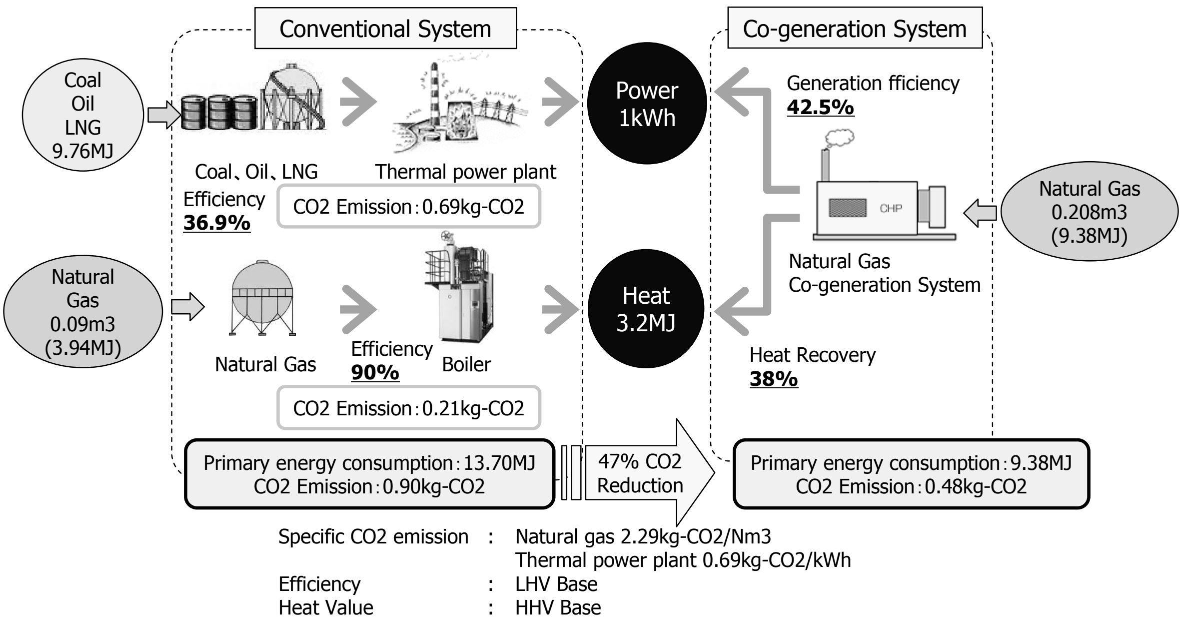


Fig.1 Comparison of CO2 Emission

3. Development concept

The development is based on the four key concepts for performance improvement (generation efficiency and total efficiency) and lower running cost of natural gas cogeneration:

1. Rated output of power generation=1MW
2. Energy saving and reduction of CO_2 emission
3. Reduction of running cost
4. Improvement of installability

The base engine is GS16R2 type that was improved from gas engine adopted into conventional gas engine cogeneration (generation output 930kW) being sold by Mitsubishi Heavy Industries now. In this development, the improvement of the power generation efficiency and the waste heat recovery efficiency was conducted. And maintenance cost reduction was attempted by the extension of the cycle of large-scale maintenance. Moreover, the new cogeneration package where the width had been narrowed more than the distances of the pillar and the pillar in the building was developed due to improvement of the indoor installability. Table 2 shows the main specification.

It individually explains four basic concepts at the following.

Table 2 Specification of GS16R2 (Development model) and GS16R (Conventional model))

Item \ Model		Development Model (GS16R2)	Conventional Model (GS16R)
Specification	Power	1000 kW	930 kW
	Generation Efficiency at Rated Power	42.5 %	40.0 %
	Hot water Recovery Efficiency at Rated Power	20.8 %	18.3 %
	Steam Recovery Efficiency at Rated Power	16.9 %	14.8 %
	Total Efficiency	80.2 %	73.2 %
	Engine Speed	1000 rpm	1500 rpm
	Top Overhaul	15000 Hr	8000 Hr
Package	Length	7500 mm	6300 mm
	Width	2500 mm	3000 mm
	Height	4600 mm	4338 mm

3.1 Output of power generation =1MW

The expectation for a cogeneration with high generation efficiency has risen as the electricity demand increases in district heating and cooling, factory and large-scale hotel. Suitable power generation capacity for district heating and cooling and the factory is around 1-2MW. But the generation efficiency in 1MW class was about 40% in the top now runner model. Therefore, it was judged that needs of high efficiency gas engine cogeneration of 1MW class whose power generation efficiency is higher than the conventional model.

Moreover, it is assumed that 1MW class natural gas cogeneration system plays a part in "Smart energy network" that promotes an efficient utilization of energy and effective use of renewable energy by management of information communication technology (Refer to Figure 2). Because the gas engine cogeneration can flexibly control the load based on signal form information communication technology, contribution to conservation of energy and CO2 reduction in the entire smart energy network is expected. When two or more offices are bundled and it forms a smart energy network, the electric power load of the network is several MW. Therefore the appropriate generation scale of cogeneration seems about 1MW.

Thus, target rated power output of the natural gas cogeneration was set to 1MW in consideration of the rise of needs of making high efficiency cogeneration in 1MW class and suitable generation output for the smart energy network of the future.

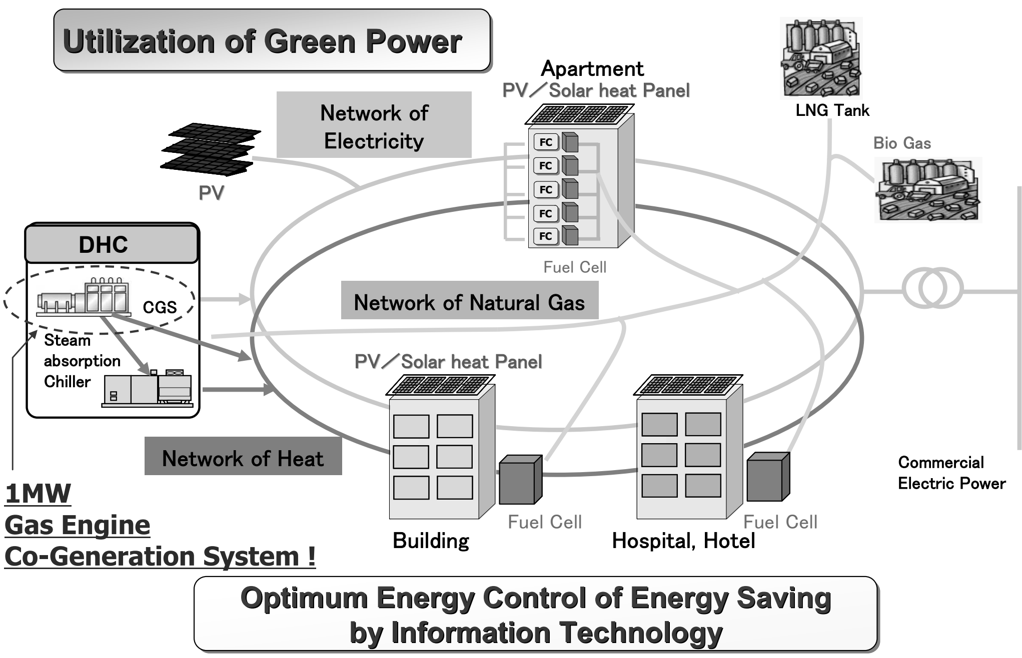


Fig.2 Image of Smart Energy Network

3.2 Energy saving and reduction of CO2 emission

It worked about two points "Made of the gas engine high efficiency" and "Improvement of the waste heat recovery efficiency" in this development to achieve energy saving and reduction of CO2 emission compare to the conventional model from the viewpoint of global warming prevention. Making the gas engine high efficiency leads to the improvement of the power generation efficiency and improvement of the waste heat recovery efficiency leads to total efficiency (generation efficiency + waste heat recovery efficiency). Thus, “Made of the gas engine high efficiency" and "Improvement of the waste heat recovery efficiency" contribute to energy saving and reduction of CO2 emission.

3.2.1 Making of gas engine high efficiency

Four approaches were executed aiming at making of the gas engine high efficiency.

1. Combustion improvement by long stroke specification
2. Reduction of friction loss by high power density and low engine speed
3. Improvement of thermal efficiency by adoption of mirror cycle
4. Reduction of pumping loss by adoption of high efficiency turbocharger

The generation efficiency 42.5% was achieved by adopting these technologies. This generation efficiency is a value more than the average efficiency of the thermal power plant in Japan.

About the knocking feared along with making of the gas engine high power density, the temperature of the fuel-air mixture at compression top dead center in the cylinder was decreased by the adoption of the mirror cycle, and the suppression of the knocking was conducted. As a result, it was confirmed to satisfy an expected knocking margin (difference between normal operation condition and knocking generation condition). When the knocking was generated, it had the function to prevent the gas engine being damaged by the knocking.

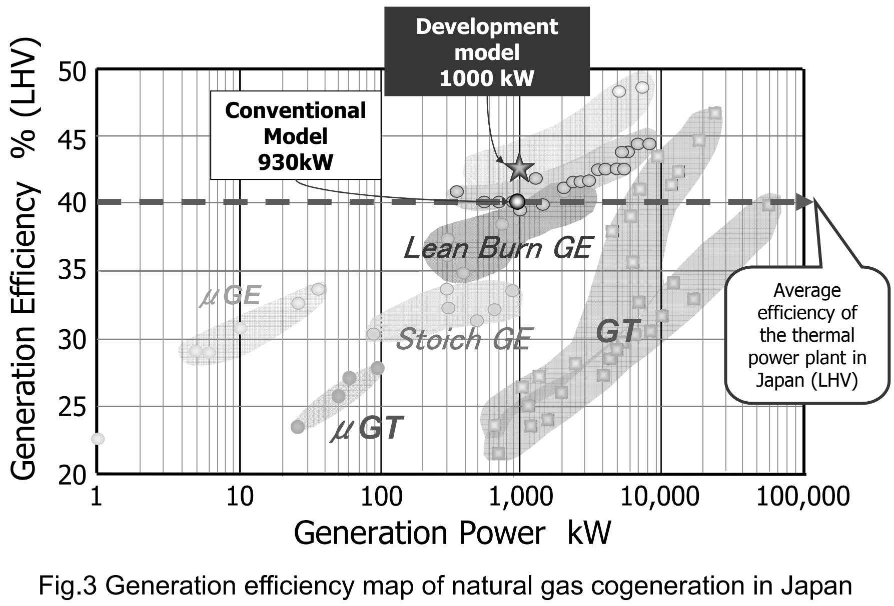


Fig.3 Generation efficiency map of natural gas cogeneration in Japan

3.2.2 Improvement of waste heat recovery efficiency

It worked about two points of "Hot water collection efficiency improvement" from the cooling water and "Steam collection efficiency improvement" from the exhaust gas of the high temperature from the gas engine for the waste heat recovery efficiency improvement in this development.

The temperature of exhaust gas equal with the conventional model was maintained for “Improvement of the steam collection efficiency” by optimizing the power generation efficiency and the exhaust gas temperature of the gas engine. Additionally, heat-transfer area of exhaust gas boiler was increased for “Improvement of the steam collection efficiency”. Moreover, the heat exchanger (hot water line) that collected heat from the fuel-air mixture of the high temperature that had passed the turbocharger was newly installed for the hot water collection efficiency improvement (Refer to Figure 4).

By the above-mentioned approach, the waste heat recovery efficiency increased and the total efficiency increased from 73.2% (conventional model) to 80.2% (development model).

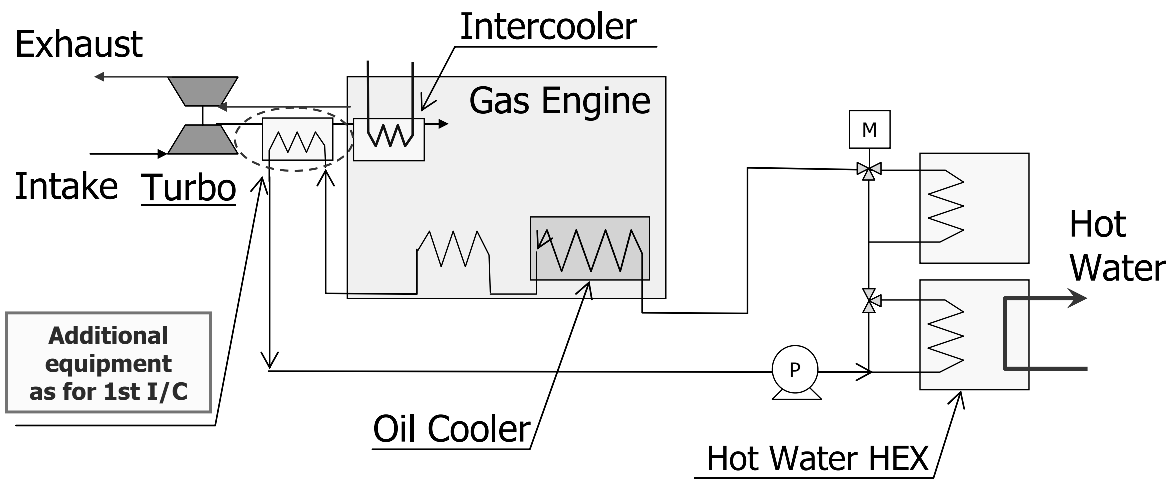


Fig.4 Schematic diagram of how water line

3.3 Running cost reduction

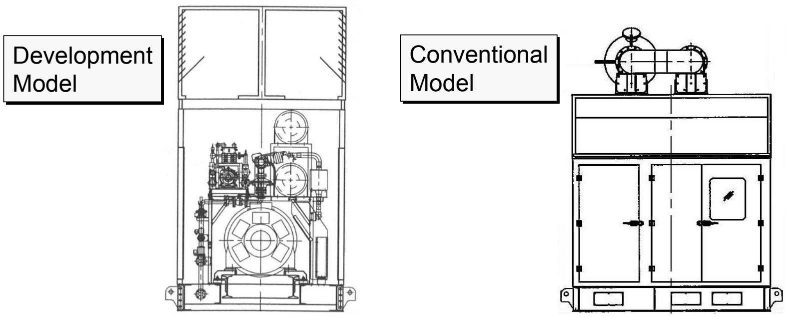
In this development, approach of running cost reduction was conducted of the high efficiency gas engine cogeneration system. Concretely, lifetime extension of sliding parts was conducted by being low speed of gas engine (1500->1000rpm). And high endurance parts were applied only about the part with a difficulty of lifetime extension by being low speed.

It is scheduled that the large-scale maintenance cycle is extended to 8000→15000Hr by the approach of the above-mentioned part exchange cycle extension, and the running cost reduction is scheduled to be achieved.

3.4 Improvement of installability

As for the gas engine cogeneration of several MW class in Japan, it is general to arrange each equipment (gas engine, generator etc...) in the cogeneration package because of viewpoints of reduction in local installation work, soundproofing, fire safety, and outdoor installation, etc.

The feature of the developed new cogeneration package is that the width is narrower than the distances between the pillar and the pillar in the building for improvement of installation into an indoor machine room. As a result, the width was set to 2500mm from a past 3000mm.



Item	Unit	Development Model(GS16R2)	Conventional Model(GS16R)
Length	mm	7500	6300
Width	mm	2500	3000
Height	mm	4600	4338

Fig.5 Comparison of cogeneration package

Next, the ventilation flow was considered to confirm whether there is an influence on ventilation performance in the package. The quality of the ventilation performance of the new package was judged from having an equal ventilation flow of the conventional model where the ventilation problem hasn't occurred. As a result, the new package was generated the ventilation flow similar to the conventional package as shown in Figure 6. So it was confirmed that cooling performance of new package is of no matter.

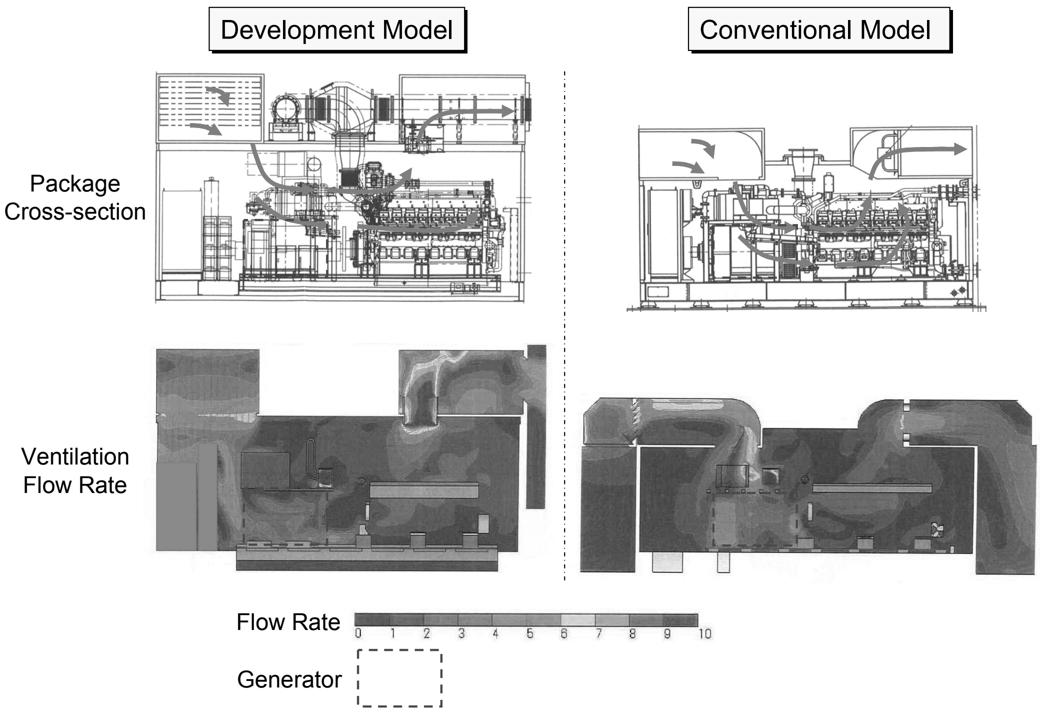


Fig.6 Consideration of ventilation flow in the cogeneration package

Developed cogeneration package is shown in Fig.7.

Fig.7 Picture of developed cogeneration package

4. Summary

The joint development of 1MW high efficiency gas engine cogeneration system was promoted, and the generation efficiency 42.5% which is top class performances in the world and high total efficiency 80% were achieved in the 1MW class cogeneration system. And for improvement of installability, the new package that was narrower than the present machine was developed.

Commercialization of 1MW high efficiency gas engine cogeneration system has been scheduled March, 2012 through the performance and the durability test.

List Tables

List of Figures