Engines for Stationary Generator in Normal Service in Domestic Market

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As deregulation and liberalization deepen in the Japan's domestic market of electric power supply, an onsite power generation business has made a great stride, being spotlighted as a new system for power supply. Traditionally power supply in this country has depended on large-scale power stations, and power is transmitted through a power cable. Now this business mode is transforming to a highly efficient network system that can supply as much power as required at the time and place of demand, thereby eliminating a loss during the transmission. This system is being gradually accepted as a system conducive to the reduction of CO_2 in the air against the backdrop of environmental protection.

Presently the mainstream onsite non-utility power generation system is a generator with a diesel engine as its prime mover. Keeping in step with the ever growing market of onsite non-utility generator sets, Komatsu's line of diesel engines has also made a rapid growth.

This paper introduces Komatsu's engine technology that has been built in the diesel engines mounted on onsite non-utility generator sets.

Key words: *Power Generation, Diesel Engine, Onsite Power Generation Business*

1. Introduction

In recent years power supply business in the Japan's domestic market has undergone a big change. In particular, competition is intensifying in the business field of onsite non-utility generators. It has been accelerated above all by the electric power companies which regard this business as part of the service industry and took part in the field. Instead of limiting themselves to a simple role of mere power supplier, they are deploying the business, keeping a comprehensive energy supply in their scope.

A micro gas turbine and fuel cell, so to speak a brainchild of new dream technology, are now emerging as a power source for the 21st century. Thus there is no doubt that power sources in this country will be diversified and an onsite non-utility generator will play a leading role of power source in the next generation.

Against such a backdrop of the industry, Komatsu-made diesel engines are being rapidly and extensively accepted in the market as a prime mover of generators in general. This fact is supported by statistics that while the market in this sector is said to have grown by 50% over the past three years, our diesel engines registered a growth rate of 40% two years ago (1999) and 22% last year (2000) respectively. (Source: Japan Engine Generator News)

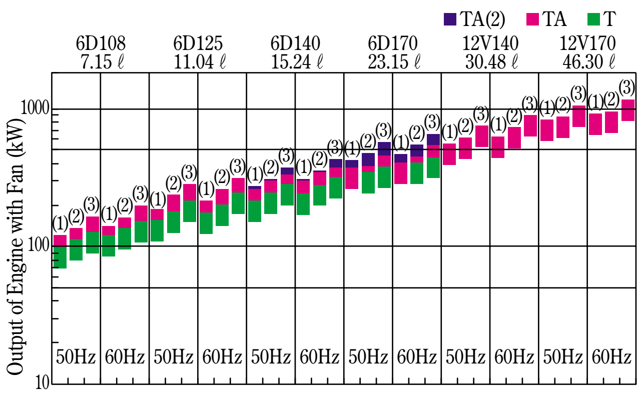
This paper takes up a lineup of our diesel engines for stationary type of generators in normal service and discusses their features as well as technology supporting the products.

2. Product lineup

Komatsu diesel engines are now provided in six series for an application to generators in normal use, namely 108, 125, 140, 170, 140V and 170V series. **Fig. 1** below shows major specifications of each series.

Boosters of the growth of the demand for onsite non-utility generators in the domestic market are large supermarkets in the outskirts of big cities, plants, hospitals, hotels and schools. Generators are installed in those buildings primarily for keeping down electricity bills. In the past when we thought of power generation facilities, we would build up an image of a power station that required a large-scale investment and generated tens of thousands of kilowatt electricity. Contrary to such general perception, the current main stream is several units of generator having a capacity of 200 to 500 kW that are installed in a package. Moreover the size of this package shows a trend of getting ever-larger. As a result, there is increasingly a demand for Komatsu's SA12V170 diesel engines, the largest in class, for generators of 800 kW capacity.

A basic factor about a non-utility generator in normal service is that its load factor exceeds 90%. For this reason, the output of our diesel engines for generator application is set after that of bulldozers, the choice from among the Komatsu's range of construction machinery. But in the recent highly competitive environment of the market, a whole power generation unit is offered on a renting basis. This is an increasingly prevailing new business model lined with an idea that customers can thereby save an investment for a diesel-powered generator set. Consequently it has given a birth to an index called a "kW Unit Price" which expresses a cost required to generate 1 kW of electricity, and this index has become an important benchmark. Now customers' expectation for a low initial cost as well as low running cost is rising high. To cope with this trend, we have switched from an aftercooler system which utilizes engine cooling water and which has been widely in use for construction equipment so far to an air-to-air aftercooler system. The latter is applied to more and more diesel engines of Komatsu to form a new series, which makes up our important strategy for widening the engine series.



(1): Onsite non-utility generator (installed as a power source mainly for large stores, plants, etc. and run continuously at a rated speed)
(2): Transportable type generator (installed as a power source mainly for construction sites and can be moved from one jobsite to another)
(3): Generator for disaster (operated as an emergency power source in case of power failure due to a disaster)

Fig. 1 Output range of Komatsu engine for generator application

3. Characteristics required of generators in normal service and realizing technology

3.1 Fuel consumption amount

The primary characteristic required of a generator in normal service is the engine fuel consumption ratio. For power generation systems using a diesel engine as the prime mover, fuel accounts for approx. 70% of the total cost. Thus the fuel consumption is a domain where an economical merit can best be demonstrated. Meanwhile, Komatsu has consummated technologies for producing small-sized but high horsepower engines.

To name a few of them:

- Piston made of ductile cast iron (**Fig. 2**)
- Cylinder liner by Tuftride method (**Fig. 3**)
- Cylinder head having dual air intake ports (**Fig. 4**)
- Air-cooled aftercooler (**Fig. 5**)

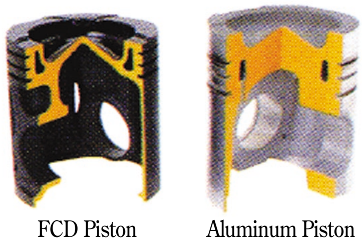


Fig. 2 Ductile cast iron-made piston

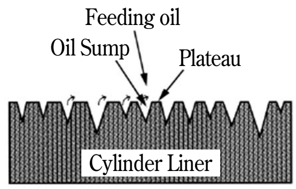


Fig. 3 Tuftride cylinder liner

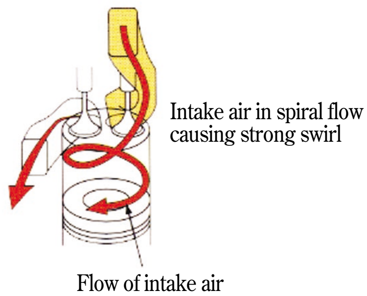


Fig. 4 Dual air intake ports

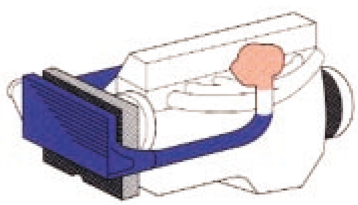


Fig. 5 Air-cooled aftercooler

3.2 Control of exhaust gas

In 1988 it was enacted in Japan to include onsite non-utility generators using a stationary internal combustion engine in the scope of Air Pollution Law. As a result, nitride oxide (NOx), soot and sulfur oxide emitted from the engine are now under control. With non-utility generators in particular, Air Pollution Law has been turned even more rigorous in its implementation, as each municipal government voluntarily imposed stiffer restriction values that exceed the original values set by the law. Thus power generation facilities relying on a diesel engine are placed under very strict conditions of use particularly in big cities. (See **Fig. 6**)

As understood from Fig. 6 below, most of the restricted municipalities fall within the category of 950 ppm regulations (in terms of 13% O_2). But Air Pollution Law resorts to a site regulation. Concentration of NOx in the emission gas is affected by humidity in the atmosphere. For this reason, the engine injection timing is set, taking into account possible changes of humidity in the atmosphere throughout the four seasons, and a complete engine clears a pre-delivery inspection that imposes stricter restrictive values than those specified by any municipality.

In addition, soot contained in the emission gas from the engine creates another problem, as generators are usually installed in the living quarters of citizens. It is also an important assignment for us to reduce the soot level. To attain this assignment, we have take steps to ensure that sufficient amount of air is fed into the engine through optimum tuning of the turbocharger and built in the fuel injection nozzles a special machining engineering that helps atomize fuel further. (Extrude horn nozzle. See **Fig. 7**)

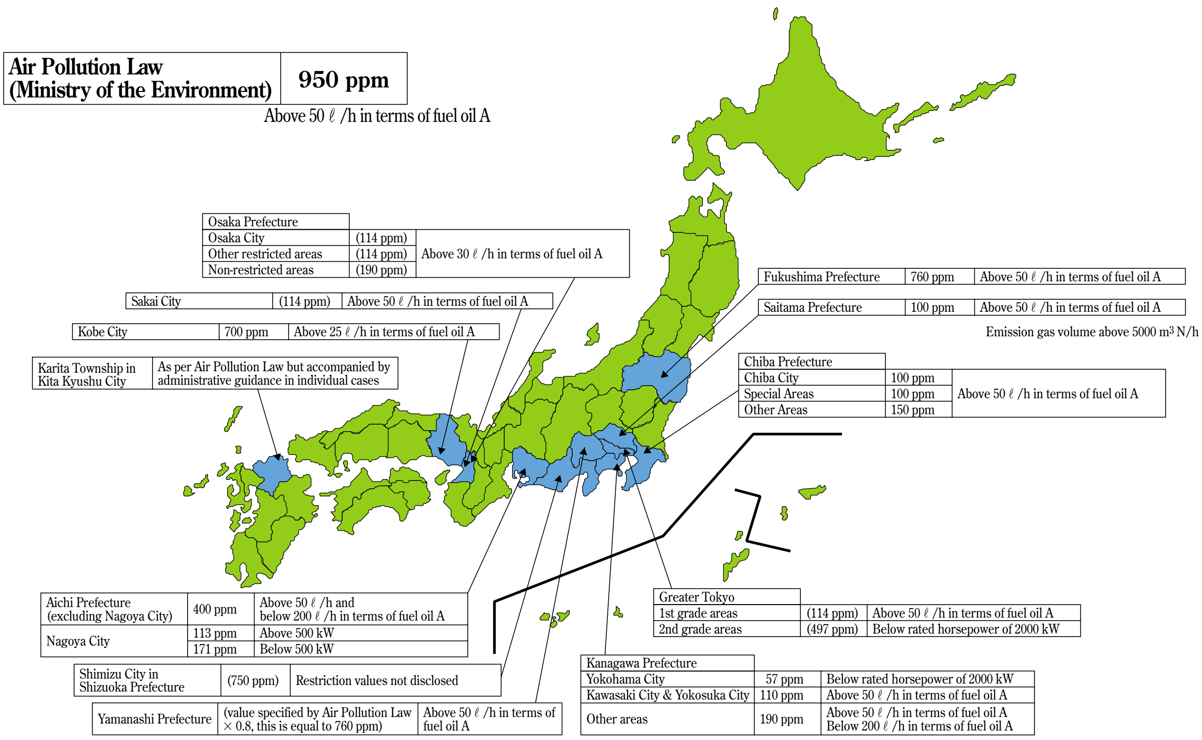


Fig. 6 Stiffer restriction values of municipalities based on the Air Pollution Law

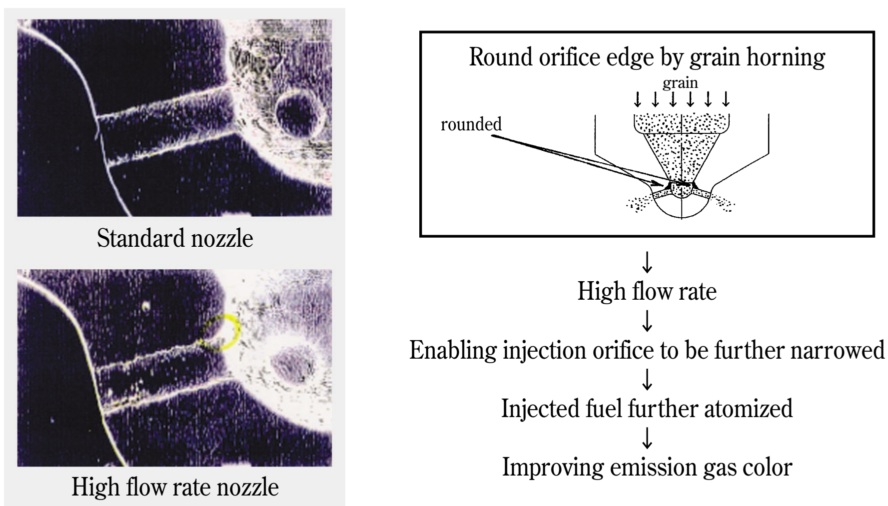


Fig. 7 Extrude Horn Nozzle

3.3 Noises

Non-utility generators in normal service are sometimes kept in operation around the clock. Therefore, it is again an important task to incorporate a noise abating technology into the engine in order to reduce noises to the neighborhood during the midnight. A hybrid fan that Komatsu has developed (see **Photo 1**) has a unique feature in its blade configuration and has successfully brought down the noise level while assuring the same amount of air feed. Komatsu's noise abating technologies have also been built in the basic components of an engine, such as a gear train which has reduced backlash and cylinder block which has enhanced the rigidity.

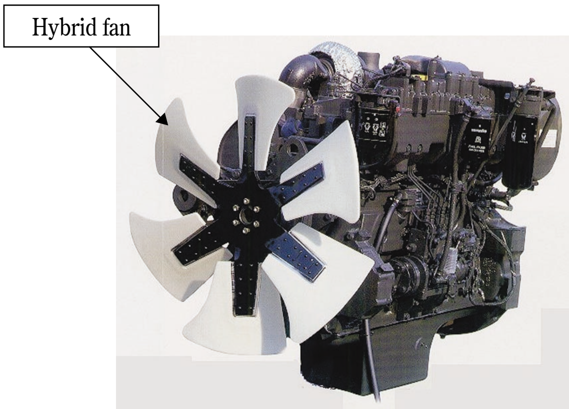


Photo 1 Hybrid radiator cooling fan

3.4 Use of electronic control technology

An electronic controlled fuel injection pump is installed on the current diesel engines for stationary generators in normal service as a standard specification, which represents merits through control technology.

A few examples for these merits are:

① In acceleration from Li to Hi, fuel injection amount is controlled through a ramp-up acceleration control in such a way that while the engine speed is swiftly raised (in about 10 seconds), the exhaust gas color is kept hardly visible (see **Fig. 8**).

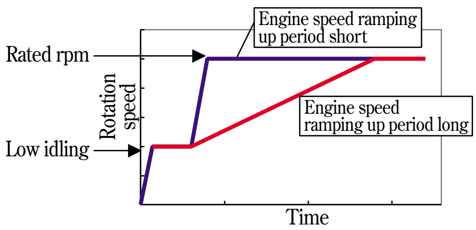


Fig. 8 Ramp-up acceleration control

② In consideration of the best matching with the generator of each manufacturer whose characteristics differ from one maker to another, an external adjustment volume is provided which enables a PID control constant to be varied.

③ A failure self-diagnosis function is provided as a standard specification (see **Table 1**). It receives and processes a signal from the generator.

Table 2 shows an assortment of functions that are supported by electronic control technology.

Table 1 Example for failure self-diagnosis function

<table>
<tr><th>Item</th><th>Failure judgment method</th><th>Time required for judgment</th><th>Action</th><th>Possibility of auto recovery</th><th>Recovery Condition</th><th>Engine status</th><th>Lamp (alarm) output</th><th>LED numeric display</th></tr>
<tr><td>Normal</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>Running</td><td>—</td><td>00</td></tr>
<tr><td>RAM in error</td><td>Write and read being incompatible at time of system ramping-up</td><td>Numeric [msec]</td><td rowspan="8">Governor pull-down</td><td rowspan="8">None</td><td rowspan="8">Turn the power OFF once and start the system again.
If no such phenomenon as described at left does not occur again, the system has been recovered.</td><td rowspan="8">Stop</td><td rowspan="8">17 pins</td><td>33</td></tr>
<tr><td>Governor servo in error</td><td>Difference between rack target value and measured value being over 1 [mm]
Ne ≦ 158 [rpm] → 10 [sec]
Ne > 158 [rpm] → 5 [sec]</td><td>Refer to left</td><td>11</td></tr>
<tr><td>Rack sensor abnormal</td><td>When rack sensor output voltage gets out of the specified range:
Above 4.5 [V] or below 0.15 [V]</td><td>150 [msec]</td><td>42</td></tr>
<tr><td>Overrunning</td><td>{Software overrunning}
• Stationary and normal service specifications:
When set at 50 Hz, Ne ≧ 1725 [rpm]
When set at 60 Hz, Ne ≧ 2070 [rpm]
• Transportable specifications:
When set both at 50 Hz and at 60 Hz, Ne ≧ 2070 [rpm]
{Hardware overrunning}
Ne ≧ 2600 [rpm]</td><td>• Normal service spec. 2.0 [sec]
• Portable spec. 100 [msec]</td><td>20 & 21</td></tr>
<tr><td>Oil pressure low</td><td>Turn the hydraulic switch ON after 6 [sec.] at Ne ≧ 500 [rpm]</td><td>500 [msec]</td><td>01</td></tr>
<tr><td>Cooling water temperature high</td><td>Turn the cooling water temperature switch ON.</td><td>0.3 [sec]</td><td>03</td></tr>
<tr><td>Source voltage abnormal</td><td>Source voltage has varied by more than 30[%] (8.4 V) as against the standard voltage (28 [V]) after 10 [sec] at Ne > 1393 rpm</td><td>Numeric [msec]</td><td>55</td></tr>
</table>

Table 2 Kinds of control by generator controller

No.	Control item	Summary of control
1	Switching frequency (50 / 60 Hz)	Frequency can be switched between 50 Hz and 60 Hz by turning on and off a jumper wire on the monitor panel. Switching frequency is not possible while the engine is running. (Frequency can be switched only when power is switched OFF.)
2	Switching between Li and rated rpm	Engine speed can be switched between Li and the rated rpm through switching input from the control panel on the generator. It can be switched when the engine is running (power switch ON).
3	Adjusting Li rotation speed	The Li rotation speed can be adjusted with a volume switch on the control panel. Adjustment range: 800 rpm ± 100 rpm
4	Switching speed droop and isochronous operation	Control of the rated rpm can be switched between speed droop control (No.5) and isochronous control (No.6) by turning on and off a jumper wire on the control panel. Switching is not possible when the engine is running. (Switching is possible only when power is switched OFF.)
5	Engine running under speed droop control	When jumper wire (No. 4) for switching between speed droop and isochronous operation is at the speed droop position, run the engine under speed droop control (the rotation speed changes as load changes). Adjust the rotation with any one of pulse signal (No. 7), analog signal (No. 8) and volume switch on the control panel.
6	Engine running under isochronous control	When jumper line (No. 4) for switching between speed droop and isochronous operation is at the isochronous position, run the engine under isochronous control (the rated rpm remains constant irrespective of changes in load). Adjust the rotation with either of analog signal (No. 8) and volume switch on the control panel.
7	Adjusting rated rpm pulse signal (Under speed droop control)	Adjust the rated rpm with a pulse signal input from the control panel on the generator. Adjustable range for speed: Approx. 3 rpm/sec. (generators in normal service), approx. 5 rpm/sec. (transportable type generators) and judgment: 50 msec.
8	Adjusting rated rpm volume (Under both speed droop and isochronous controls)	Adjust the rated rpm with the volume switch on the control panel. Judgment: 15 msec.
9	Adjusting rated rpm analog input (Both under speed droop control and isochronous control)	Adjust the rpm with an analog signal input from the control panel on the generator. Adjustable signal range for speed: DC 1 – 5 V
10	Switching between rotation adjustment analog and pulse signals (Under speed droop control)	The rated rpm adjustment method can be switched between pulse signal input (No. 7) and analog signal input (No. 9) by turning on and off a jumper wire on the monitor panel. Switching is possible even when the engine is running (when power switch ON).
11	Switching between rotation adjustment analog and volume signals (Both under speed droop control and under isochronous control)	The rated rpm adjustment method can be switched between volume switch adjustment (No. 8) and analog signal input (No. 9) by turning on and off a jumper wire on the monitor panel. Switching is possible when the engine is running (when power switch ON), but an error mark is shown on the display.
12	Speed droop adjustment (Under speed droop control)	Regulation can be changed with the volume switch on the control panel when the engine is running at the rated rpm. Adjustment range: Approx. 3 – 5 %
13	Excessive acceleration limiting function (Speed lamp function)	When the rated rpm is selected with the Li/rated rpm selector switch, this function controls the time required for the engine rotation to rise from Li to the rated rpm (approx. 10 sec.), thereby keeping down black smokes. The function is also activated when the engine starts up with the selector switch at the Hi position.
14	Switching speed lamp ON and OFF	Use or nor use of the speed lamp control can be selected by turning on and off a jumper wire on the monitor panel. Switching is not possible when the engine is running. (It is possible only when the power switch is OFF.)
15	Emergency stop function	The engine is stopped automatically when a serious trouble occurs, such as when the engine oil pressure lowers abnormally; the engine cooling water temperature rises abnormally; or the engine is overrunning.
16	Failure self-diagnosis function	If any abnormality occurs on the electronic governor system, this function is activated to take specified corrective actions and sends out a failure signal. Output: Numeric display on the controller and failure- indicating lamp going on (For more details, see Troubleshooting Table.)
17	Memory clearing function	History of the failures stored in the memory can be cleared by pressing the memory clearing button on the control panel.
18	Switching to excessive speed testing mode (Not to be used in other than test)	Testing an excessive speed is made possible by turning on and off a jumper wire on the monitor panel. Do not use this mode while the engine is running. (It may be switched only when the power switch is OFF.)
19	PID adjustment function	Control constants can be changed with the volume switch on the control panel so that the generator can be set at an optimum value in terms of its stability and responsiveness.
20	ON/OFF switching for PID adjustment	“Allowed” or “Not Allowed” of adjusting PID constants can be selected by turning the volume on the control panel through the function of the jumper wire on the control panel. (Not Allowed = using a constant from the internal data) Switching is not possible when the engine is running. (It is possible only when the power switch is OFF.)
21	Output of engine starting motor pinion slip-off signal	Engine startup is detected and a relay signal is sent out.
22	Engine pre-lubrication function	Cranking without fuel injection is made possible by the switch on the control panel.

3.5 High reliability and durability

Generators in normal service are required of high reliability and durability for its nature of fundamental facilities. In this respect, Komatsu has held up 16000 hour overhaul-free maintenance schedule of the engine as one of its sales features ahead of the other competitors. Based on the use in the construction equipment, history of individual engine parts is stored in a database. Then far-flung improvement of the engine parts has been devised, making use of such database and taking into account peculiarities in the application of the engine to generators in normal service. Included in the improvement are a change of the shaft seals for a longer service life, change of the material used in the fuel injection system from a rubber hose to metal piping, engine oil selection standard to match the nature of fuel, increasing the oil pan capacity, providing a bypass filter as a standard specification, increasing the fuel filter capacity (to deal with fuel oil A), anti-corrosive measure against sulfur content in fuel, etc. An assortment of such improvements enabled us to achieve a 16000 hour overhaul-free maintenance schedule of our engines.

In addition, the table for scheduled engine maintenance has been revised, setting up an inspection interval as A Inspection (every 500 hours), B Inspection (every 1000 hours), C Inspection (every 2000 hours), D Inspection (every 4000 hours), E Inspection (every 8000 hours) and F Inspection (every 16000 hours). A maintenance work standard and a table for replacement parts at each inspection time are prepared. Potential clients of Komatsu engine-mounted generators make the most of these informative materials when computing a generator running cost.

4. Future prospect

Competition in the onsite non-utility generator in normal service is stiffening, as the market continues to expand. As we discussed in the preceding chapter, a mission of onsite non-utility generators lies in proving its economy. How can our diesel engines be an economical prime mover under the prevailing stringent environmental restrictions? That will decide whether we can stay in the market as a winner in the future. At any rate, irrespective of how the market evolves from now on, I trust that the two fundamental requirements of the market, namely ① less fuel consumption mount and ② lower maintenance cost will remain unaffected. There should be no change in clients' aspiration of them from now, either.

5. Conclusion

Sales of Komatsu diesel engines for generator application has grown so high that currently the sales ratio accounts for more than 50% of the total demand including those for other applications. This is fruit of all the efforts and hard work of those who have been engaged in the generator engine business to date. It is believed that a demand for power will be still on the rise in the 21st century, too, and that enhancing merchantability of the products even more is essential to remain in the market. In this regard, we are fortunate to possess an FCD piston-based low fuel consumption technology and a construction equipment-based technology for prolonging replacement part service life, which surely meet with requirements in the today's market. It is no exaggeration to claim that thanks to those technologies, Komatsu's engine brand is disseminating in the domestic market stationary non-utility generator sets. We will maintain the brand while making further improvements on our engines. To do this, we need feedback of a wide spectrum of market information and above all voices from clients about their requirements. We will keep a clearer focus on them.

Introduction of the writers

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[A few words from the writers]

A number of Komatsu-made diesel engines have been so far adopted by the Japan's generator manufacturers as an OEM engine. You may come across one in a shopping center or plant in your neighborhood that is working day and night. Basically it is a result of the engine performance (like fuel consumption as reported in this paper) that has been accepted by the clients. But broadly it should be a result of the joint efforts of all the Komatsu people concerned that went into the improvement of reliability and durability of the engine as well as after-sales service including replacement parts supply system.

We pledge to continue with our efforts for improving or developing our diesel engines from now on, too, to ensure a supply of "inexpensive power of high quality" to our clients at large.