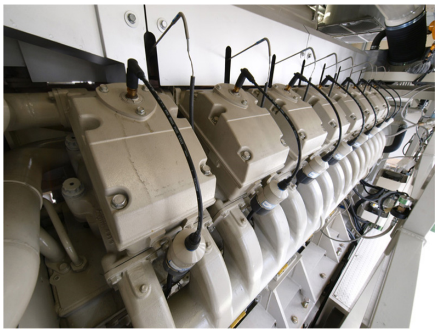
# Development of High-efficiency 2MW High-speed Gas Engine (Completes 9,000+ Hour Validation)



**Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.**

*In the segment of distributed power sources, power generation by means of a gas engine holds an important position since gas engines emit less CO2 from burning natural gas than coal and heavy oil, i.e., its exhaust emissions are cleaner and its thermal efficiency is fairly high. Nevertheless, the key that attracts customers and motivates them to purchase one is how economical the unit price of a gas engine power generation is, compared with the unit price of power from the grid. Namely, the product merchantability is dependent on the realization of appealingly high generation efficiency. It is also key to design the engine with the smallest dimensions possible, especially for installation at sites in urban areas.*

*To meet these needs, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. has been developing the new 2MW-class G16NB gas engine, which features the world's most advanced combustion control and turbocharging technologies (**Figure 1**). An overview of the G16NB engine is described below.*

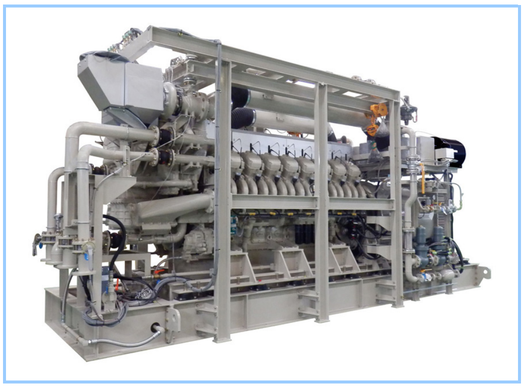


**Figure 1 G16NB gas engine**

## 1. Features

### 1.1 Pre-chamber initiated lean-burn combustion

The G16NB engine adopts lean-burn technology to achieve both higher thermal efficiency and lower NOx emissions. The difficulty of ensuring constant and stable ignition per cylinder, a typical problem for lean-burn engines, has been solved for the G16NB engine by means of the pre-chamber torch jet ignition system.

### 1.2 Miller cycle

In case where the premixed combustion is selected, abnormal combustion (engine knocking) often occurs because the higher compression ratio causes increase in both temperature and pressure in cylinders. To avoid this known problem, G16NB engine has employed Miller cycle that can increase the expansion ratio without increasing the compression ratio to control the elevation of in-cylinder temperature and thereby avoid engine knocking. To this end, early intake valve closing strategy has been applied.

### 1.3 Two-stage turbocharging system

G16NB engine uses two-stage turbocharging system to achieve higher output and efficiency.

The air compressed by the lower-stage turbocharger is cooled by the intercooler and transferred to the higher-pressure turbocharger so as to enhance the overall turbocharging system efficiency. This ultimately contributes to reducing the pumping loss and increasing thermal efficiency.

### 1.4 Wastegate valve

Whereas gas engines in general use an intake throttle valve to control the air-fuel ratio, the G16NB engine controls the air-fuel ratio by changing the turbocharger speed via a wastegate valve. This control can eliminate the risk of pressure loss by the throttle valve, resulting in even higher thermal efficiency.

### 1.5 Ignition timing control

While ignition timing advancement is effective in increasing the degree of constant volume and thermal efficiency, it cannot avoid engine knocking. By detecting engine knocking during operation and giving feedback control to ignition timing, continuous operation with high thermal efficiency has been ensured for the G16NB engine. The engine adjusts the ignition timing according to the vibration readings from the acceleration sensor provided for each cylinder, computes the knocking intensity using MHIET's proprietary logic and uses it to control the ignition timing for each cylinder.

## 2. Main specifications

The main specifications of the G16NB engine and the GS16R2 engine currently on the market are shown in **Table 1**. Although the engines have exactly the same displacement, the G16NB engine has achieved higher output and generation efficiency, which indicates that the G16NB engine has the greater advantage and value as a distributed power source. The generating efficiency of the G16NB engine is 44.7%, which is one of the world's highest among 2MW-class high-speed gas engines.

**Table 1 Main specifications of the new G16NB* gas engine and the existing GS16R2 gas engine**

| Engine model | | G16NB | GS16R2 |
|---|---|---|---|
| Engine output | kWe | 2000 | 1000 |
| Engine speed | $min^{-1}$ | 1500 | 1000 |
| Generation efficiency based on lower heating value | % | 44.7 | 42.3 |
| Cylinder bore x stroke | mm | 170×220 | |
| Cylinder layout/Number of cylinders | ― | V type/16 cylinders | |
| Displacement | L | 80 | |
| Turbocharger | ― | Two-stage turbocharging | Single-stage turbocharging |

* Values represent current performance and specification, subject to change before placing on the market.

## 3. Future action

The G16NB engine has been operating in a co-generation package supplying electricity and heat to be used in MHIET's own Sagamihara factory (**Figure 2**). Using this demonstration package, the engine is being evaluated for reliability over the long term under actual operating conditions and improvements are made as appropriate. The combined service hours of the development G16NB engine and this demonstration G16NB engine exceed 9,000 hours, and the soundness of the major components has been verified in inspections. Feedback from the evaluation and validation will be implemented in the production G16NB engine to be marketed as a gas engine cogeneration system.


**Figure 2 2MW gas engine power generation package**