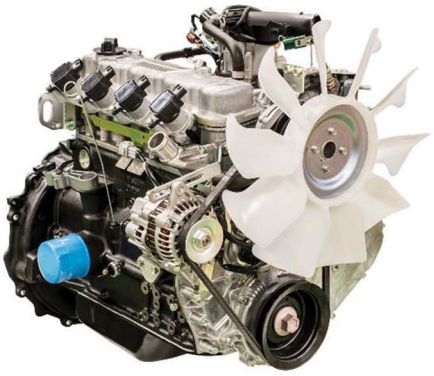
K type Engines for Forklift Trucks and Gas Heat Pumps



Global Component Technology Corporation

Global Component Technology Corporation (hereinafter GCT) is a wholly-owned subsidiary of UniCarriers Corporation, which is a group company of Mitsubishi Heavy Industries Forklift, Engine & Turbocharger Holdings, Ltd. (M-FET). GCT has been developing, producing, and selling industrial machinery engines since its time as the Industrial Machinery Division of Nissan Motor Co., Ltd. One of their main products is the K type, a 2.0-liter class, spark-ignited, in-line four-cylinder engine mainly for forklift trucks and gas heat pumps (GHP). This paper presents the features of the K type engine.

1. Summary of GCT's industrial machinery engines

GCT's engines, based on proven, sophisticated engines for automobiles over the years, have been optimized by new designs for forklift trucks and GHP applications in response to requirements and customer needs.

Common requirements include the capability to deal with gas fuel that has fewer lubricating components in comparison to gasoline and diesel fuel, the durability and reliability suitable for various use conditions and environments, the enhancement of fuel efficiency and thermal efficiency, etc.

The K type engine, which is based on knowledge and technologies cultivated through long-term results and experiences of the preceding H type engine, was brought to the market as an engine exclusively for industrial machinery in 2003 after understanding various market needs through use of the QFD (quality function deployment) method and an overall review of the design. Thereafter, variations were added and improvements were made based on market and customer needs. **Figure 1** shows the main variations of K type engines.

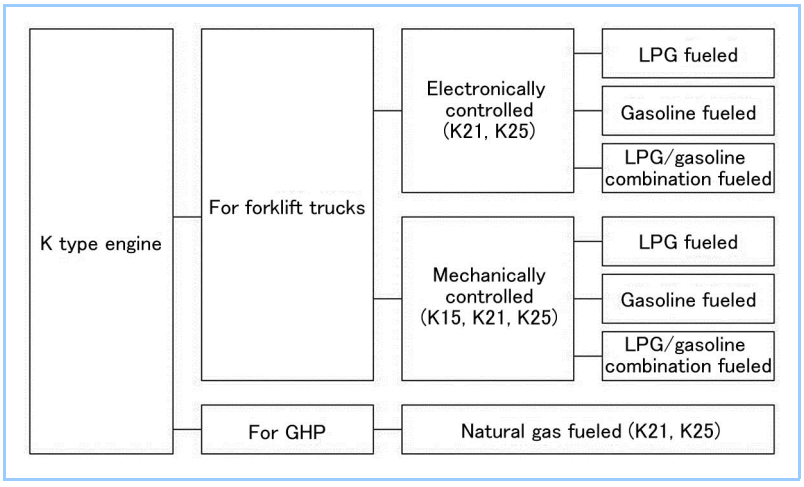


Figure 1 Variations of K type engine

2. Engines for forklift trucks

There are two types of K type engines for forklift trucks: electronically controlled and mechanically controlled. Each of the two includes LPG fueled, gasoline fueled, and LPG/gasoline combination fueled types based on the type of fuel used.

There are three variations of engine displacement (1.5-liter, 2.1-liter, and 2.5-liter), and they utilize a common packaging to enhance efficiency for installation on vehicles. These engines are supplied to many foreign forklift truck manufacturers, as well as all domestic forklift truck manufacturers other than Toyota Motor Corporation, including Mitsubishi Nichiyu Forklift Co., Ltd. and UniCarriers Corporation, which are M-FET group companies.

Table 1 Specifications of engines for forklift trucks

	K21		K25	
	Non-electronically controlled	Electronically controlled	Non-electronically controlled	Electronically controlled
Displacement (cc)	2065	2065	2488	2488
Bore x Stroke (mm)	89.0×83.0	89.0×83.0	89.0×100	89.0×100
Fuel	Gasoline & LPG	Gasoline & LPG	Gasoline & LPG	Gasoline & LPG
Compression ratio	8.7	8.7	8.7	8.7
Rated power output (kW)	31.2	41	35.6	46.9
Rated engine speed (min^{-1})	2200	2700	2250	2700

Table 1 shows the engine specifications. The features of the electronically-controlled type, as a representative example, are described below.

(1) Capability to deal with gaseous fuel (LPG)

Parts specifications are optimized in order to secure durability and reliability for use with gaseous fuel.

[1] Intake and exhaust valves

[2] Valve seats and valve guides

[3] Piston rings

(2) Control system

Figure 2 shows a control system of an engine for forklift trucks. An engine for forklift trucks requires governor control of the engine rotation speed in order to protect the hydraulic pump for cargo handling. To meet this requirement, independent governor control of the electronically-controlled throttle chamber is adopted.

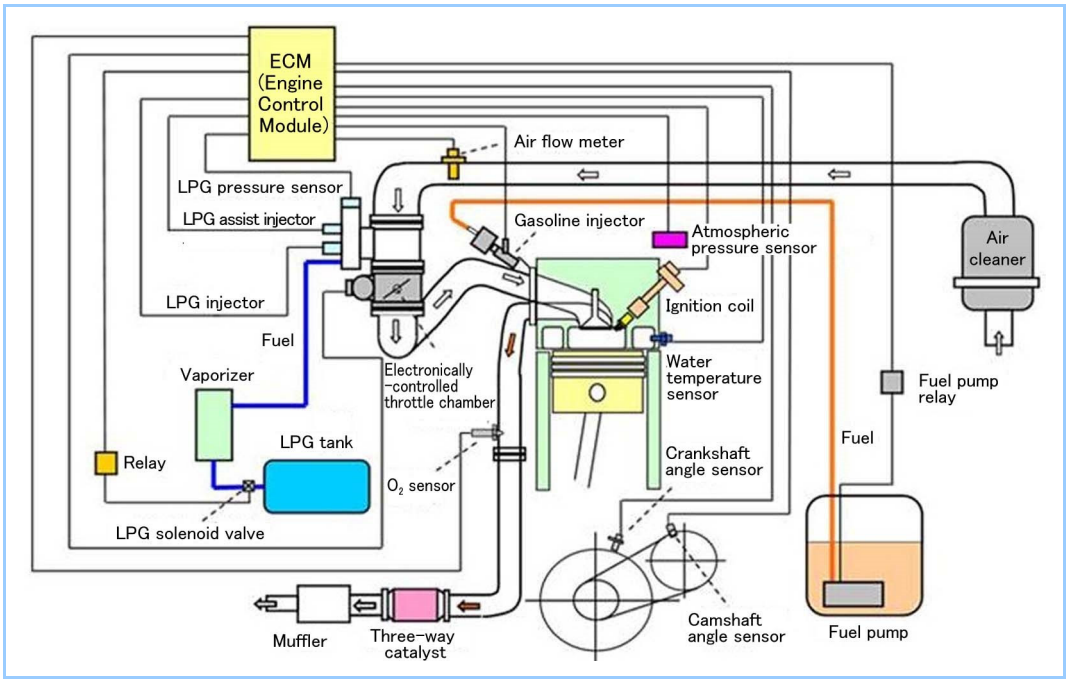


Figure 2 Control system of engine for forklift trucks

In addition, GCT's unique LPG gas injection TBI (throttle body injection) system is adopted. The fuel efficiency and the operability are enhanced, the exhaust gas is cleaned, gasoline/LPG combination fuel control is adopted, maintainability is enhanced using the self-diagnostic control and vehicle speed limiting control, which contributes to the safe operation of the forklift truck, is adopted.

(3) Output performance

For engines for forklift trucks, torque at low and middle engine rotation speeds is more important in comparison to automotive engines. For this reason, the following were optimized:

[1] Shape of combustion chamber
[2] Compression ratio
[3] Shape of intake manifold
[4] Valve timing

3. Engines for GHP

Table 2 shows the specifications of engines for GHP. Optimizations to meet the requirements of engines for GHP were made while progressing with communalization with engines for forklift trucks.

(1) Enhancement of thermal efficiency

To attain the the highest thermal efficiency in the region of GHP usage, the following specification enhancements were made.

[1] Shapes of combustion chamber and intake and exhaust ports
[2] Increase of compression ratio
[3] Optimization of valve timing (mirror burn)
[4] Lean burn

(2) Enhancement of durability

Engines for GHP are required to have higher durability in comparison to vehicle engines and forklift truck engines because of their many hours of continuous operation. Therefore, the following specification enhancements were made.

[1] Improvement of the valve sliding parts (valve seats and valve guides)
[2] An ignition system that deals with the higher secondary voltage required by lean burn operation
[3] Enhancement of starter specifications in response to increased frequency of switching the engine on/off

Table 2 Specifications of engines for GHP

	K21	K25		
	16PS	30PS	20PS	16PS
Displacement (cc)	2065	2488	2488	2488
Bore x Stroke (mm)	89.0×83.0	89.0×100	89.0×100	89.0×100
Fuel	13A, LPG	13A, LPG	13A, LPG	13A, LPG
Compression ratio	13.5	14.0	14.0	15.5
Rated power output (kW)	14.0	21.0	15.8	15.2
Rated engine speed (min^{-1})	1900	2000	1500	1800

4. Future prospects

Currently, strict exhaust gas regulations have been applied to spark ignition type engines for forklift trucks in Japan and North America. In 2019, further stringent exhaust gas regulations will also be introduced to Europe. We hope to support the development of the industrial machinery business by evolving our products to contribute to further cleaner exhaust gas and the reduction of CO_2 in consideration of global environmental protection.