



DUAL-FUEL ENGINES

MODEL DF752

[17.1 kW (23.0 HP) with Gasoline or 16.4 kW (22.0 HP) with LPG]

Kubota has recently introduced two Dual-Fuel Engines — models DF752 and DF1005 — that operate with either gasoline or LPG. Developmental goals included adhering to regulations concerning emissions and being exceptionally economic to operate.

Formerly, two separate carburetors — one for gasoline and another for LPG — were required. No longer! Models in the DF-Series feature the newly developed Dual-Fuel Carburetor (patented by Kubota) that is capable of effectively regulating both gasoline and LPG. Further, it is possible to instantly switch between fuels even while the engine is running.

To obtain information concerning this unique Kubota development and the many advantages it offers, the team



Mr. Keiichi Nakano (KN):
Section Chief of the Liquid-Cooled Gasoline/LPG Team within the Engine Engineering Department, Mr. Nakano supervised overall design and research.



Mr. Akira Inoue (AI):
As Research Section Chief, Mr. Inoue was responsible for the pertinent test procedures and research plans adhering to the guidelines set forth by Mr. Nakano.

Mr. Fumio Yamashita (FY):

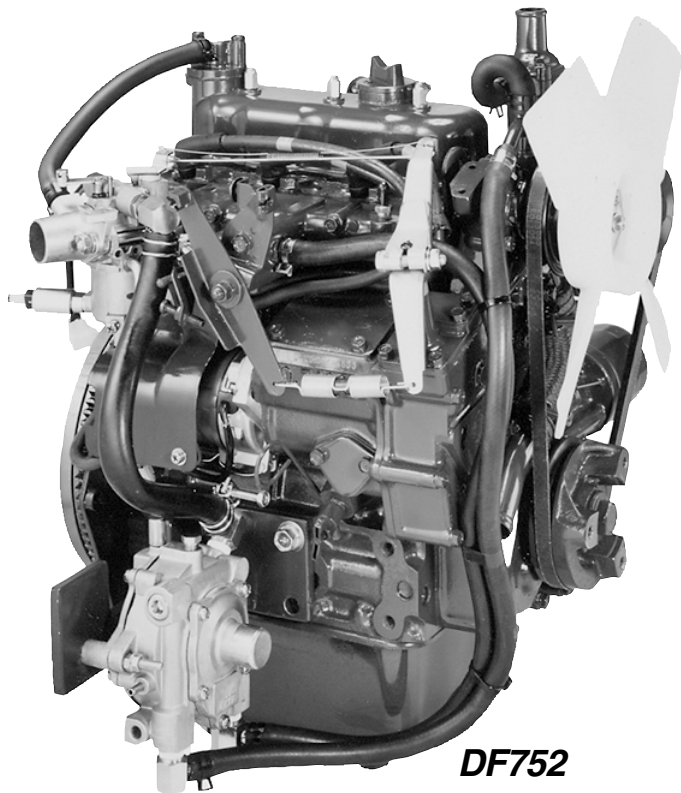


This Assistant Section Chief was mainly responsible for the design — using a diesel engine as the base — that permits the use of either gasoline or LPG.

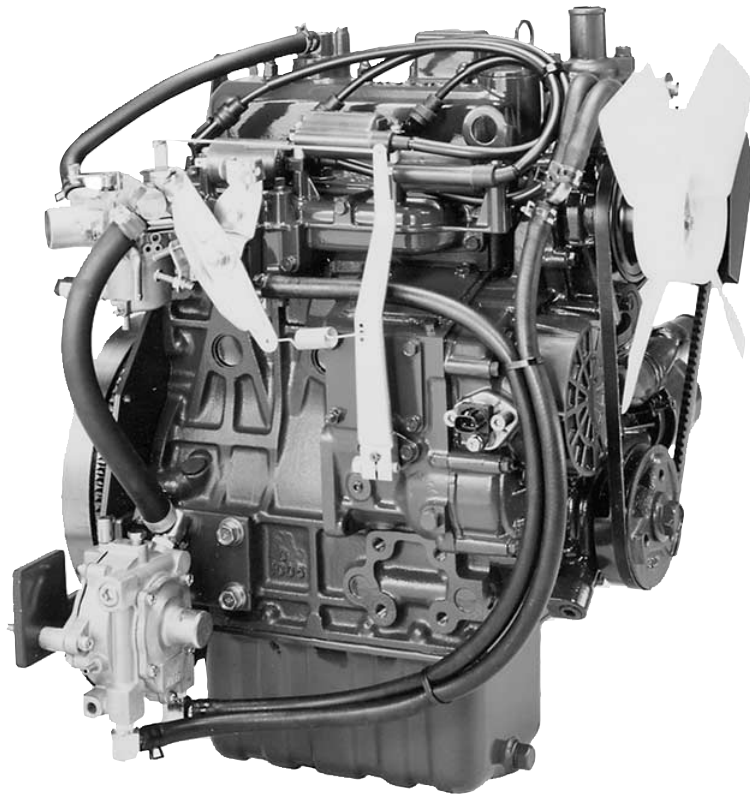
Mr. Yutaka Teru-umi (YT):

Mr. Teru-umi was principally responsible for conducting practical tests to evaluate engine performance to eliminate all possible problems.





DF752



DF1005

Adhering to Tough EPA/CARB Phase2 Emissions Regulations

► In what kind of applications is the Dual-Fuel Engine especially useful?

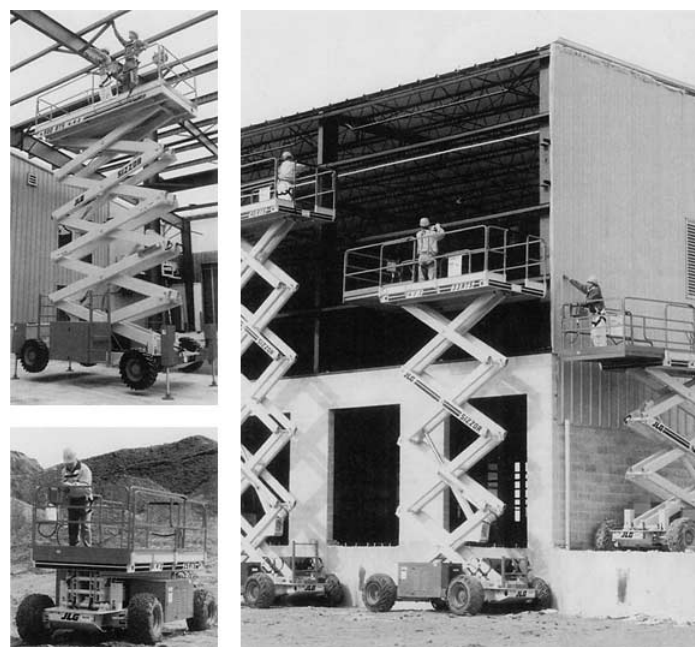
KN: The main market is the USA; primarily in Aerial Lifts operating back and forth between indoors and outdoors. Indoors they use LPG with clean emissions while outdoors they use gasoline that is more economical.

AI: The Dual-Fuel Engine was developed to satisfy two basic requirements; to be environmentally-friendly indoors while being as economic as possible to operate.

► Was it the implementation of emissions regulations that was responsible for the development of the Dual-Fuel Engine?

KN: As a matter of fact, prior to that time an LPG Kit was available that could be fitted to a gasoline engine to convert it to a Dual-Fuel Engine. Following the full-scale implementation of emissions regulations in September 1997, however, modifications made after shipment were no longer permitted.

Kubota innovation was then applied to meet market demand for an engine clearing that phase 1 regulations by developing the model DF750 Dual-Fuel Engine that quickly became



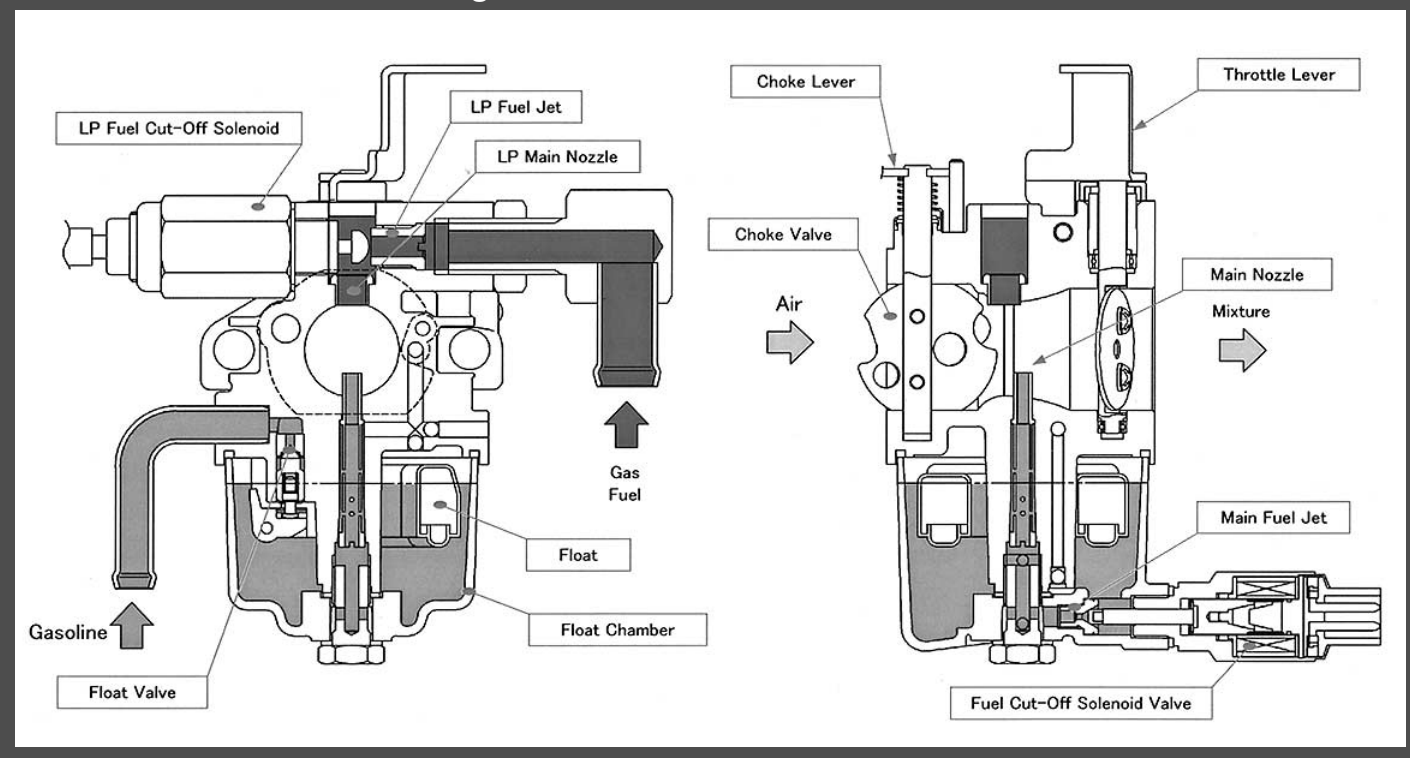
Aerial Lifts with Kubota Dual-Fuel Engines mounted.

a hit product with sales of nearly 3,000 a year.

AI: The EPA is promulgating stricter regulations for engines rated at or below 19 kW to be applied in 2001. CARB will do the same in 2002. To clear these phase 2 regulations, we upgraded model DF750 to develop model DF752.

At the same time, we responded to requests from users seeking greater output to bring forth model DF1005 in the

Dual-Fuel Carburetor Flow Diagram



over 19 kW category that will be subject to CARB regulations — in the 1 liter or less class — from 2002.

The Newly-Developed Dual-Fuel Carburetor Enables Customers to Replace the Previously Available Diesel Engine with an Engine of the Same Size with Identical Mounting Condition

► What were the objectives in developing the DF-Series?

AI: They included:

1. Bringing forth an engine adhering to emissions regulations.
2. Ensuring that such an engine would offer the low noise and vibration advantages of spark ignition engines while maintaining the high-quality, exceptional durability, and superb reliability for which the Kubota Diesel Engine that forms its foundation is renowned worldwide.
3. Maintaining the same mounting specifications and dimensions as the Kubota Diesel Engine upon which it was formed.

All these requirements were realized by both model DF752 and model DF1005. Following the development of the DF-series, OEM customers — those who use Kubota Diesel Engines with equivalent specifications and dimensions

— would be able to utilize the Dual-Fuel Engine models without making any design changes regarding application.

► What was your principal concern at the beginning to retain the same dimensions?

FY: The carburetor! In previous models, two carburetors — one for gasoline and another for LPG — were utilized. However, this configuration required more space than we were able to allocate. Therefore, we developed a compact Dual-Fuel Carburetor to control both gasoline and LPG. Further; two solenoids in the switch are responsible for making possible an instant changeover between fuels.

Patented by Kubota, this unique carburetor has contributed to making the Dual-Fuel Engines fitted to the DF-Series the world's first to attain certification for the EPA (USA), and CARB regulations.

Attaining Adherence to Regulations at Low Cost

► How hard was it for the Dual-Fuel Engines to clear the strict emissions regulations?

FY: The fact that they are Dual-Fuel Engines was not a stumbling block. However, for such a multi-cylinder engines to adhere to the regulations it was necessary to evenly

distribute the fuel-air mixture sucked into each cylinder.

YT: Achieving even distribution with a single carburetor was definitely an obstacle we had to consider. To overcome the fact that a large part of the fuel mixture is likely to flow into the cylinder located nearest the carburetor; we prepared as many as 11 kinds of inlet manifolds with varying forms and carburetor mounting angles. It was necessary to closely check such factors as the density of carbon monoxide and exhaust temperature before determining which configuration was most effective. In fact, patent applications are being filed for various innovations including the form of the inlet manifold and the carburetor mounting angle.

FY: From the manufacturing point of view we had to develop engines that would not only deliver optimum performance while adhering to emissions regulations, but that would also be cost effective with as few parts changes as possible.

YT: To accomplish this, we applied our Quality Engineering Method that concentrates on factors with a high contribution rate to the development process. Let me explain that! If tests are conducted combining ten different factors in sequence, it may require tests be repeated several thousands of times. With the Quality Engineering Method, however, the number of tests required to effectively determine which parts had to be changed was reduced to a dozen or so.

FY: Another positive factor was that for model DF1005 Distributorless Digital Ignition was introduced for the first time in the industry. This is important because it allows freely setting the timing of firing. As a result, the fuel mixture is ignited at the most appropriate so that emissions are cleaner and overall performance is

enhanced. Further, combustion is reliably stable due to the fact that there is no fluctuation such as occurs with the mechanical type of ignition.

► How have users reacted to Kubota Dual-Fuel Engine since model DF750 was first introduced in 1997?

KN: It has been widely accepted for Aerial Lifts in the USA; in fact, the DF750 — the engine that adhered to the phase 1 emissions regulations — is currently used by 7 out of the 10 major Aerial Lift makers in the country.

As was mentioned earlier, model DF1005 was developed to adhere to the phase 2 regulations as well as to respond to requirements of OEM customers seeking an enhanced product.

► What do you see as the future prospects for the DF-Series?

KN: At present these models are used mainly for Aerial Lifts and Sweepers. Looking to the future, however; applications for the DF-Series will further be expanded — taking advantage of “simple fuel switchover” and “clean emissions” — to include forklifts and other types of equipment that are predominantly used indoors.

AI: Along with the DF-Series, the gasoline-only models WG752 and WG1005 have been added to our extensive product line. Since models in the WG-Series have dimensions not unlike those for diesel engines, OEM customers are now able to select from among Gasoline, Dual-Fuel, or Diesel Engines; all with the same mounting specifications.

Kubota Positively Tackles Future Emissions Regulations

► Do you think regulations will become more stringent in the future?

KN: Probably! Therefore, Kubota — in adherence to its concerns regarding global environment — is constantly focusing on the improvement of both performance and cost competitiveness as well as on the timely adherence to the worldwide emission regulations. In fact, researchers are already looking several years ahead to prepare for the next-generation of regulations. This preparedness gives OEM customers confidence in Kubota engines now and into the future.

► That is very enlightening. Thank you very much for joining us today.

