FOCUS ON KUBOTA

KUBOTA DIESEL ENGINES

Versatile 4-Cylinder, 16-Valve, Center Direct Injection System Engines
The First Industrial-Use Diesel Engines in this Class

ubota Diesel Engines perfectly match the wide range of equipment upon which they are mounted there by receiving full marks for their superb reliability, versatility, and economic cost of operation.

In 1997, the marketing edge for Kubota Diesel Engines in the over 50 PS categories was boosted as a result of launching the 3-valve type V3300 IDI (Indirect Injection) in response to customer demand for enhanced output. A high-output Diesel Engine that was both compact and lightweight, it was Kubota's first over 50 PS engine designed primarily for OEM-applications as well as captive use. In addition to a large-capacity Side Take-Out PTO that was the largest for any engine in this class, its features included the ability to select the mounting positions for the Fan, Starter, and Oil Filter as well as selecting maintenance access from one of three directions.

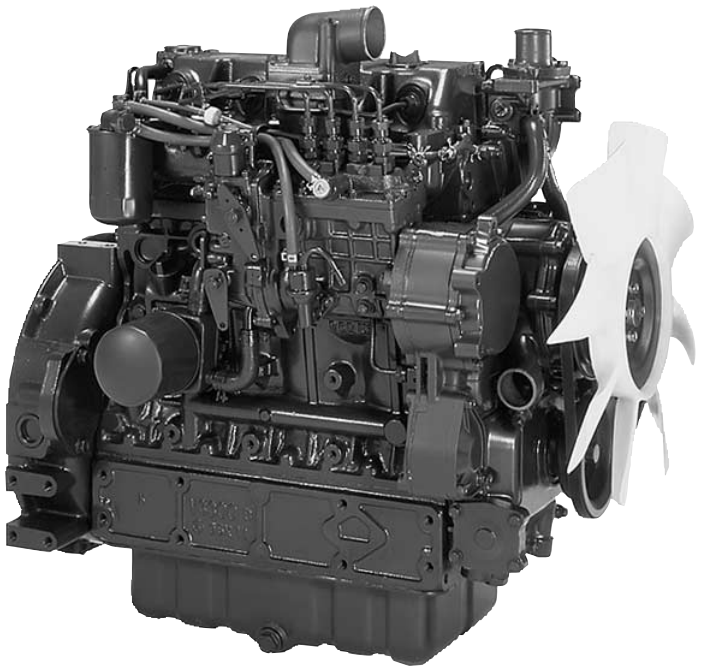
Not content to rest on its laurels, Kubota — following the same design philosophy as with the IDI model — then went to work developing models V3300DI (Direct Injection) and V3300DI-T [Turbo], and then added them to the series in August 2000. These engines feature even greater output as well as enhanced performance that have been made possible by incorporating the 4-Valve Per Cylinder Center Direct Injection System (E-CDIS) for the first time in 3L-Class Industrial-Use Diesel Engines. Needless to say, as environmentally friendly Kubota products they also satisfy the ever more stringent gas regulations.

To obtain a clearer picture of how the "E-CDIS" Models V3300DI and V3300DI-T came to be, the Kubota Times interviewed the team responsible for their development.

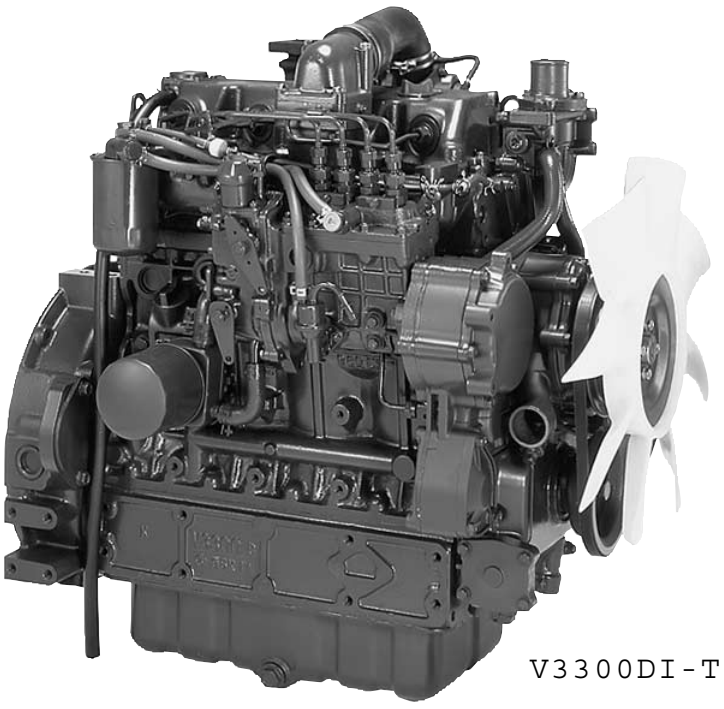
Mr. Kiyoshi HATAURA (KH)
Deputy Manager, Engine Engineering Department
Mr. Hataura – having been vitally involved in the development of the V3300IDI – was selected the Development Team Leader to oversee every step from the original concept and research through the resulting design of these new engines.

Mr. Manabu MIYAZAKI (MM)
Project Engineer, Engine Engineering Department
Previously involved in the design of the V3300IDI, Mr. Miyazaki was the ideal choice to become the Design Section Leader for this project.

Mr. Osamu TAKII (OT)
Project Engineer, Engine Engineering Department
Mr. Takii – formerly involved in combustion studies for the V3300IDI – was involved in the development of these models as the Research Section Leader.



V3300DI



V3300DI-T

Unique Engines with Enhanced Capabilities

► Weren't the capabilities of the previously available model V3300IDI sufficient to satisfy customers' requirements?

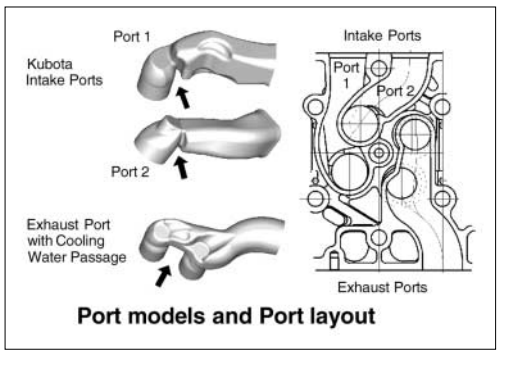
KH: It earned wide acceptance since it was launched in 1997 by delivering greater capability than any engine previously available in the 50 PS and larger categories. It was good, but an awareness of emerging users' needs led us to focus on direct injection to further boost Kubota product capability in this class.

In fact, engines in this class are required to deliver an enhanced level of output if they are to be utilized by fully equipped, high-capacity machinery. Further, they must contribute to preserving the global environment by featuring exceptional fuel efficiency while adhering to the stringent exhaust regulations promulgated by the Environmental Protection Agency (EPA) of the USA that are scheduled to be strengthened in January 2004. In a very competitive field, this meant developing Industrial-Use Diesel Engines with Kubota's unique characteristics; models that would be fuel-efficient, have clean exhaust, and would satisfy the ever more sophisticated and diversified needs of users.

To fulfill the varied requirements, it was decided to incorporate the 4-Cylinder, 16-Valve, Center Direct Injection System; a method by which an Injection Nozzle is placed vertically at the center of each of the 4 cylinders while the 4-valve structure of each cylinder — 2 for intake and 2 for exhaust — enhances intake & exhaust efficiency. Though such a system was previously available only on large capacity engines due to its complex structure, Kubota found the way to incorporate it in engines rated between 50 and 100 PS.

The 4-Valve Center Direct Injection System (E-CDIS)

► It sounds like a very difficult undertaking?



Port models and Port layout

KH: Well, four valves per cylinder results in each cylinder head having 2 Intake Ports and 2 Exhaust Ports so the only a limited amount of space remains to fit the Injection Nozzle with its accompanying Cooling Water Passage. The answer was the innovative introduction of an Injection Nozzle and Cooling Water Passage that together measure only 17 mm in diameter.

► This appears to be another outstanding example of the Kubota preeminence in compact technology.

Valves for Optimum Air Intake Volume and Swirl

► What is the reason a 4-Valve System has been incorporated?

OT: The primary objective of using a 4-Valve System is to enhance output by increasing the efficiency of Air Intake. In a 2-Valve System with a single Intake Valve, the Air Intake Port has to be made narrower to strengthen Swirl; an arrangement which actually reduces Air Intake Volume. To increase Intake Air Volume, it was decided to incorporate the 4-Valve System with 2 Intake Valves.

Though efficient to a point, the ordinary 2 Intake Valve System — composed of a Helical Port mainly for generating Swirl and a Direct Port mainly for increasing Air Intake Volume — would not have permitted us to achieve our goal of significantly increasing Air Intake Volume. Therefore, it was decided to use the Direct Port for both Intake Valves.

► What is the effect on Swirl?

OT: Unless the proper compensation is made, air entering directly through the 2 Intake Ports would have had the effect of further weakening Swirl. To overcome that, Kubota original Intake Port was developed that contributes to the generation of a powerful Swirl as it increases the Air Intake Volume.

In the past, the models for testing Swirl were made of wood. In the development of this system, however, transparent plastic models were produced that significantly reduced testing time. Not having had previous experience with a 4-Valve System, we had to feel our way along step-by-step. Finally, however, persistence paid off! We succeeded in securing optimum Swirl performance by regulating the flow of air in a direction opposite that of Swirl. This became possible because along the way we developed and optimized the form of Kubota original Intake Port.

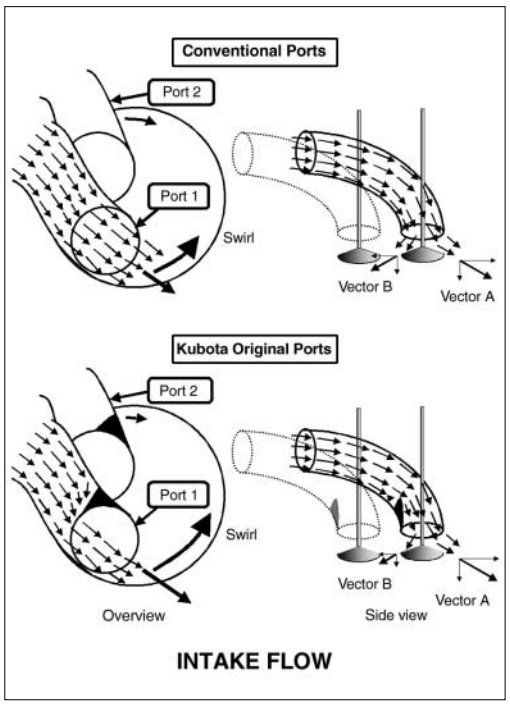
Reliable Fuel Injection System

► Wouldn't that mean a large Fuel Injection Pressure?

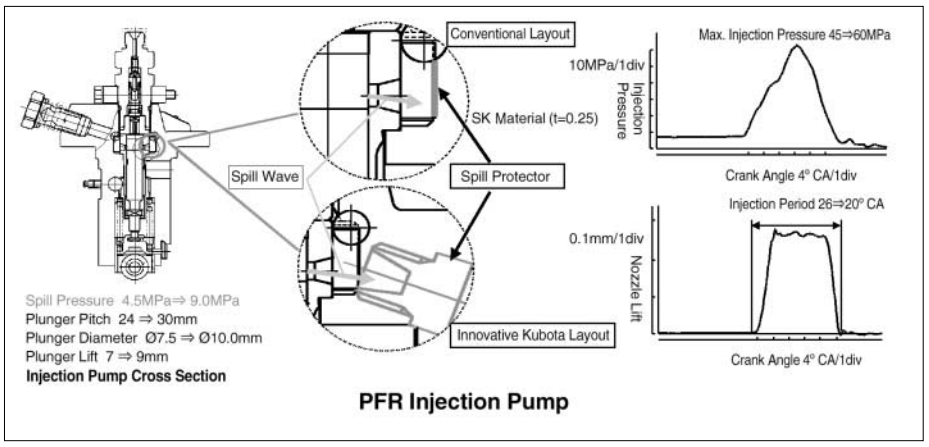
MM: Yes, it would. Compared to the IDI configuration, it is harder for fuel to mix with air in the DI configuration because fuel and air mixture heavily relies on Swirl and Fuel Injection Energy. To achieve as fine a spray of fuel particles as possible, Fuel Injection Pressure was raised to 60 Mpa as opposed to only 40 Mpa for IDI.

One problem with DI that we had not experienced with IDI concerned pressure as it is released following the completion of Fuel Injection. After reaching a pressure of as high as 60 Mpa, the fuel instantly reverts to almost 0 Mpa. The consequence is an Impact Wave (Spill Wave) along with Cavitation — the formation of partial vacuums in the flowing mixture as a result of the separation of its parts. The collapse of those partial vacuums can cause pitting or other damage on the internal surface of the Cylinder. To remedy this, the amount of the Spill Protector has been increased while the composition and form of the Cylinder has been improved.

Another problem was that Injection Pump Vibration also increased as a result of the higher pressure. This required developing improved vibration resistance and making changes to parts of the Governor Mechanism. By positively overcoming these and other problems we encountered,



INTAKE FLOW



PFR Injection Pump

reliability was enhanced.

KH: Like the IDI configuration, the DI configuration incorporates the Injection Pump fitted with Kubota's unique Governor Mechanism. This makes possible the external regulation of Fuel Injection Volume at both the Rated Output and at Peak Torque. Industrial-Use Diesel Engines are fitted to various types of machinery; each with its own output characteristics. For machinery that operates within a limited range of revolutions, Torque Rise is not a critical factor. On a tractor, however, Torque Rise varies dramatically in response to the job-at-hand and terrain conditions. That means it has to have the tenacity to ensure the engine won't stop even if revolutions suddenly drop due an increased load. Precision control of the rate and timing of Fuel Injection at both the Rated Output and at Peak Torque are, therefore, vital factors contributing not only to the maximization of Engine Output and the tenacity, but also for being in compliance with exhaust regulations. As it is necessary to match all these factors in coordination with improvements made in the equipment on which the engine is fitted, the External Adjustment Function makes the job easier and more precise.

High Output and Clean Exhaust Superbly Balanced

► What effect does Direct Injection have on noise and vibration?

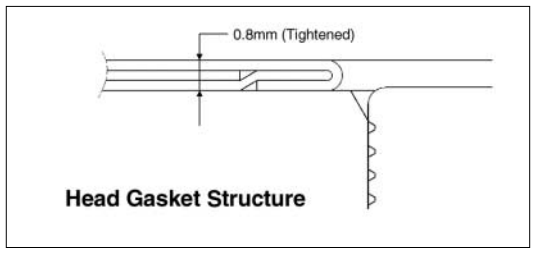
KH: Innovative Kubota engineering led to the incorporation of several advances contributing to significantly diminished levels of both noise and vibration in these new models. Examples include the Center Direct Injection and the built-in Dynamic Balancer that feature reduced vibration while a decrease in Piston Slap Noise was made possible by applying Molybdenum Disulfide to the Piston Skirt with the effect of easing friction between the Piston and the Liner and thereby permitting the 3-stage opening valve type Thermostat to be fitted so that a smaller clearance between the two parts became possible.

► Seemingly a contradiction, how is it possible to deliver higher output with cleaner exhaust?

OT: Primarily, this is an added advantage of incorporating Center Direct Injection System. As fuel is uniformly injected from the nozzle, it combines more effectively with the air inside the Combustion Chamber so that combustion is more uniform. This translates into an enhanced basic engine performance while reducing exhaust emissions.

In addition, tuning the engine performance characteristics is — like the IDI configuration — easily accomplished externally. After the engine is turned on, adjustments are made while checking Dynamometer readings. This permits making maximum effective use of Engine Output at a level that perfectly complies with Exhaust Regulations.

MM: Another contributing factor relates to the introduction of the 3-layer type Steel Gasket for the Head Gasket. By reducing redundant volume at the Top Dead Center of the Piston, a more stabile exhaust performance is obtained. This is such an important advantage, in fact, that this type of Gasket is now being used on the IDI configurations as well.



Head Gasket Structure

► How does output of the DI versions compare with the IDI?

KH: Output was improved by 4.4% for the DI configuration and 7.5% for the DI-T configuration. Torque Rise is set at 23% for the DI model and at 28% for the DI-T.

Product Assortment Responds to Users' Requirements

► The V3300 Diesel Engine is now available in the IDI, IDI-T, DI, and DI-T configurations.

KH: That is correct. As a result, customers have a wider range of configurations to select the one best suited for the equipment in which it will be fitted.

► What about the future of DI-type engines?

KH: They will experience greater acceptance as exhaust regulations become tougher.

► Finally, what is the future forecast for Kubota Diesel Engine development?

KH: Steps will be taken to further upgrade product marketability in the 50 to 100 PS categories. Specifically, further enhancements of the IDI and DI configurations should contribute to achieving a greater market share. And in the Kubota tradition, every step necessary will be taken to provide the finest possible service and customer support.

► Thank you very much for joining us today.