Introduction of Products

Hydro Static Transmission Forklift Models FH60-1, FH70-1, and FH80-1

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The 6-8 ton class engine-powered forklift trucks, FH60-1, FH70-1, and FH80-1, have been developed and introduced into the market as larger capacity trucks of the FH series. Previous models FH35-1, FH40-1, FH 45-1, and FH 50-1 are Komatsu's first forklift trucks that are equipped with an electronically controlled hydrostatic transmission and a closed-center load sensing system with a variable pump. Based on Komatsu's hydraulic technologies, the FH60-1, FH70-1, and FH80-1 have been greatly improved over the existing models. This paper describes the new technologies introduced in the new FH60-1, FH70-1, and FH80-1 models.

Key Words: *Forklift, Electronically controlled hydrostatic transmission, Closed-center load sensing system, Multi-monitor, KOMTRAX, Low fuel consumption, Environment, Safety, ICT*

1. Introduction

With the increased global awareness of environmental problems and higher crude oil prices in recent years, demands for low fuel consumption and reduced environmental load are rapidly increasing. To meet these demands, we set out to develop medium-sized forklift trucks that use a hydrostatic transmission, and brought to market the 4-5 ton class engine-powered forklift trucks FH40/45/50-1 in July 2012. (Model FH35-1 was added in July 2013.) FH35/40/45/50-1 has been highly rated in the market for the great improvements in fuel consumption and operability.

To expand the lineup of the FH series with larger capacity models, we have developed 6-8 ton class forklift trucks. Based on the high rating of the electronically controlled hydrostatic transmission in the market, we have brought into the market the FH60/70/80-1, which feature improved operability. These models are outlined below (**Fig. 1**, **Table 1**).

Fig. 1 FH80-1

Table 1 Major specifications

Item		Unit	New model FH80-1	Current model FD80-10
Performance and dimensions	Maximum load	kg	8000	8000
	Load center	mm	600	600
	Maximum travel speed	km/h	23.5	31
	Wheelbase	mm	2300	2300
	Tread (front wheels/rear wheels)	mm	1540/1640	1540/1640
	Vehicle weight	kg	11280	10910
Engine	Manufacturer	-	Komatsu	Komatsu
	Model	-	SAA4D95LE-6	SAA4D95LE-5
	No. of cylinders/Total displacement	-/cc	4/3260	4/3206
	Rated net output	kW/rpm	63.9/2150	69.0/2250
	Fuel tank capacity	L	177	140
Information	ICT	-	KOMTRAX	-
Fuel consumption	In-house standard course A (Comparison with current model)	-	70	100

2. Aims of Development and Approach

(1) Compliance with emission regulations

- Complies with the Japanese emission regulations (Tier 4 Interim) in 2011.

(2) Up to 30% reduction in fuel consumption (as compared with the current FD80-10 model).

- Reduces power transmission losses by introducing an electronically controlled hydrostatic transmission.
- Achieves low fuel consumption in high-load work by controlling engine output according to the weight of load.
- Reduces hydraulic pressure losses when operating work equipment while driving the vehicle by introducing a closed-center load sensing system with a variable pump.

(3) Improvement in drivability and operability

- Improves drivability by introducing an electronically controlled hydrostatic transmission.
- Improves operability in creepless driving, starting on slope, and switching back.
- Improves inching performance for work in harbors and container work. (*)
- Reduces operating force using proportional pressure control for work equipment. (*)
- Improves holding performance by improving the operator's seat. (*)

(4) Improvement in safety

- A travel speed limiting function is equipped as standard.
- Adds a seat belt caution display. (*)

(5) ICT

- Improves visibility and functionality with a color LCD multi-monitor.
- Improves KOMTRAX, which was introduced in the FH series as standard. (*)

(*): First introduced in the FH60-1, FH70-1, and FH80-1.

3. Major Components

Based on the features of the FH series, the new models have been equipped with an electronically controlled hydrostatic transmission that has been used on wheel loaders and bulldozers, and a closed-center load sensing system with variable pump.

The engine is equipped with a diesel oxidation catalyst and variable flow turbocharger, in addition to the conventional commonrail electronic control, to comply with Tier 4 Interim emission standards (**Figs. 2** and **3**).

Like FH35/40/45/50-1, the major components have been internally developed and manufactured to provide high reliability and productivity using the technologies we acquired in the field of construction equipment.

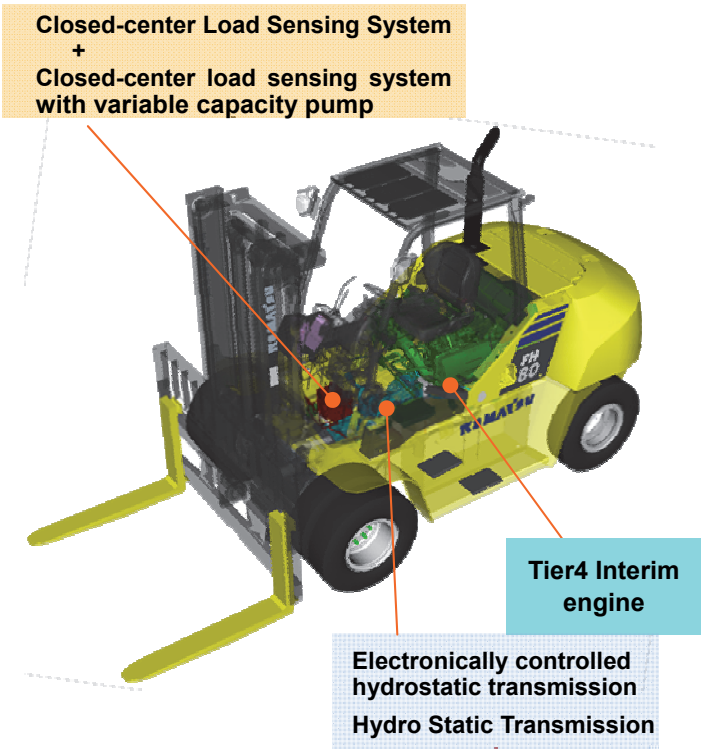


Fig. 2 FH80-1 general view

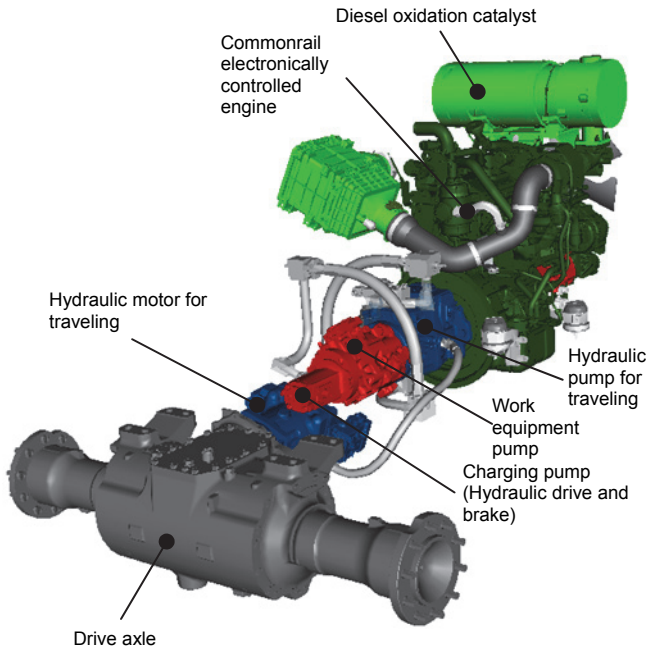


Fig. 3 Major components

4. System Overview

4.1 System configuration of FH60/FH70/FH80

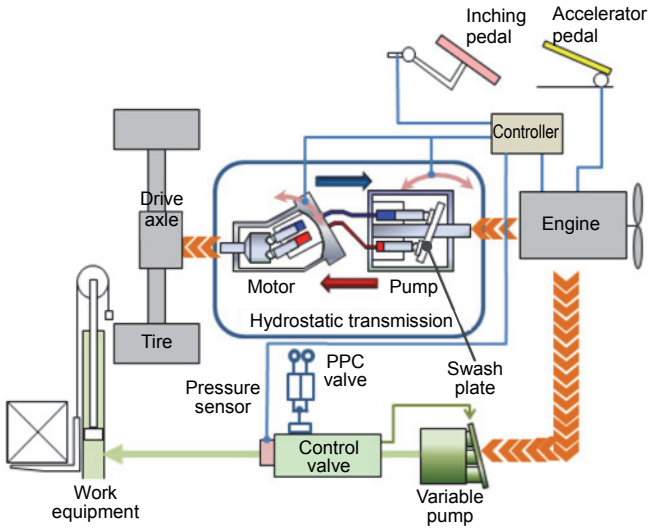


Fig. 4 System configuration of electronically controlled hydrostatic transmission vehicles

Fig. 4 shows the system configuration of electronically controlled hydrostatic transmission vehicle models FH60/70/80-1. This configuration is similar to that of FH35/40/45/50-1.

The engine drives the pump to generate hydraulic pressure, which is converted back to a rotational force by the motor. Changing the angle of the swash plate that is connected to the pistons changes the piston stroke, which continually increases or decreases the flow rate of hydraulic oil to control the travel speed. Thus, stepless control from normal rotation to stopping and reverse rotation can be performed by changing the swash plate angle. The neutral swash plate position stops the stroke of the pistons, generating the same effect as applying the brake.

The inching and accelerator pedals send electronic signals to the controller, which outputs EPC current to the pump and motor based the specified conditions so that the pump and motor capacities are determined according to the operator's intention.

A variable pump is also used in the hydraulic system for the work equipment so that the required amount of oil is supplied based on signals from the control valve.

5. Reduction in Fuel Consumption

5.1 How forklift trucks are used

Forklift trucks are often used in limited spaces where acceleration, stopping, switching between forward and reverse travels, and simultaneous load handling and vehicle travel occur frequently. Such uses are more common on sites handling high load with a high operating ratio (such as in recycle businesses), where fuel consumption tends to be greater and users are more interested in reduction in fuel consumption. Taking into consideration such work sites where low fuel consumption gives a great benefit to users, the following technologies are used to achieve low fuel consumption.

Fig. 5 Example of high load work of forklift truck

5.2 Technologies for low fuel consumption

(1) Reduction of heat losses and slip losses

In simultaneous load handling and travel operations of a torque converter equipped vehicle, the inching pedal is used to adjust clutch slip and control travel speed, which generates clutch slip losses and heat losses.

On hydraulic drive vehicles, on the other hand, since

travel speed is controlled by changing the pump swash plate angle to change the flow rate of oil, instead of slipping the clutch, heat or slip losses do not occur, achieving low fuel consumption.

(2) High efficiency in low speed ranges

The torque converter (3-element/1-speed/2-phase) generally used in forklift trucks provides high efficiency in high-speed ranges because of a free wheeling, but suffer from large agitation losses in low-speed ranges, resulting in lower efficiency than the hydraulic drive system (**Fig. 6**).

Although hydraulic drive vehicles provide better acceleration for traveling, the engine is controlled to restrict rev-up, thus reducing fuel consumption during acceleration without sacrificing travel performance.

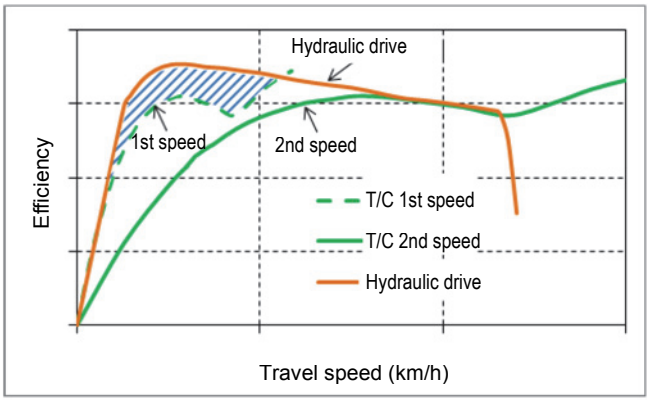


Fig. 6 Travel efficiency

(3) Optimizing engine output

Using measures (1) and (2) described above, the maximum engine output was reduced by approximately 8 percent from the conventional torque converter equipped vehicles, resulting in lower fuel consumption.

(4) Low-speed matching

In general, the fuel consumption ratio is lower near the engine speed where the maximum torque is obtained than that near the rated engine speed.

The hydraulic pump's absorption torque matching point with respect to the engine has been set closer to the maximum torque from the torque converter's absorption torque. This has allowed the range with low fuel consumption to be used for a long time during acceleration, contributing to low fuel consumption (④ in **Fig. 7**).

(5) Shifting engine torque curve at no load

There is a great difference in vehicle weight between when a forklift truck is carrying a load (loaded condition) and not carrying a load (unloaded condition). On FH35/40/45/50-1, the weight of a load is detected by a sensor to restrict engine output at light load conditions, thus reducing fuel consumption. We have improved it a step further on FH60/70/80-1 and implemented stepless control of engine output according to load, achieving even lower fuel consumption (⑤ in **Fig. 7**).

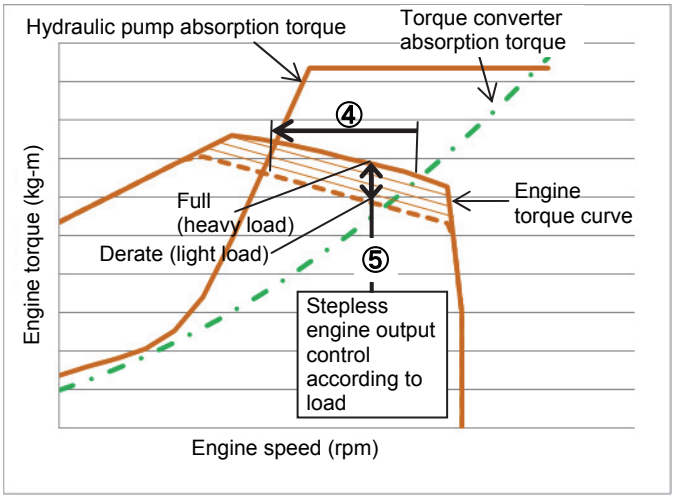


Fig. 7 Matching with engine

(6) Closed-center load sensing system with variable pump

The hydraulic system for work equipment in forklift trucks typically uses a gear pump (fixed capacity), which supplies more amount of oil than necessary, creating hydraulic losses.

The same as FH35/40/45/50-1, FH60/70/80-1 uses a closed-center load sensing system with a variable pump. By keeping the pressure difference between the pump delivery pressure and the required pressure of each work equipment constant, the necessary amount of oil is supplied, thus reducing hydraulic losses (**Fig. 8**).

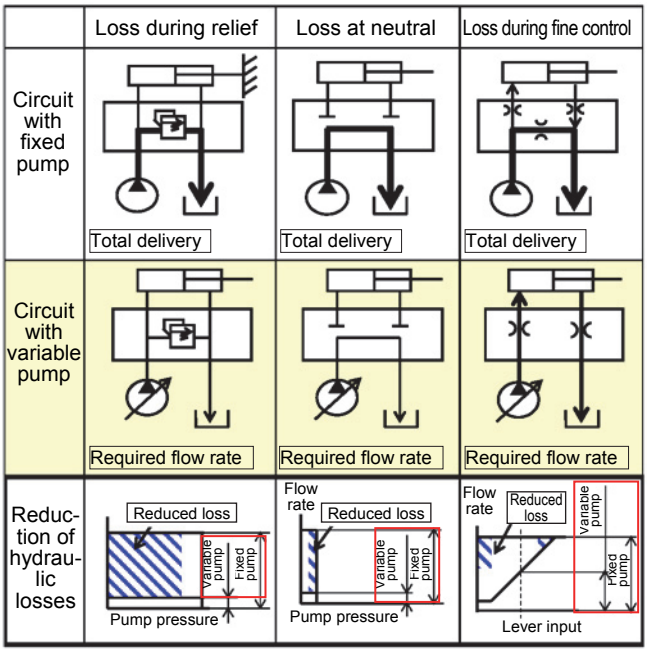


Fig. 8 Reduction of hydraulic losses in work equipment

6. Results

6.1 Reduction in fuel consumption

Fig. 9 shows the reduction in fuel consumption on in-house standard courses.

A significant reduction in fuel consumption has been attained (up to approximately 30%) not only on the high-load course (A), which requires frequent switching back at short distances to simulate loading work on trucks, but also on the low- to medium-load course (B).

Fig. 10 shows the frequency distribution of engine speed and torque on the high-load course (A). The larger a circle, the greater the distribution. The smaller circles are shifted to the low fuel consumption side as compared with previous models. In particular, changes in the engine speed are small during acceleration, which allowed the low fuel consumption range to be used over a long period of time, achieving the desired reduction in fuel consumption.

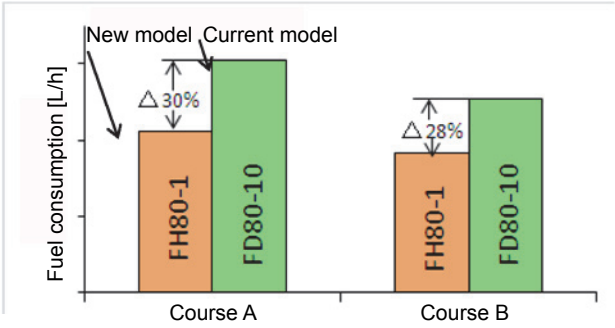
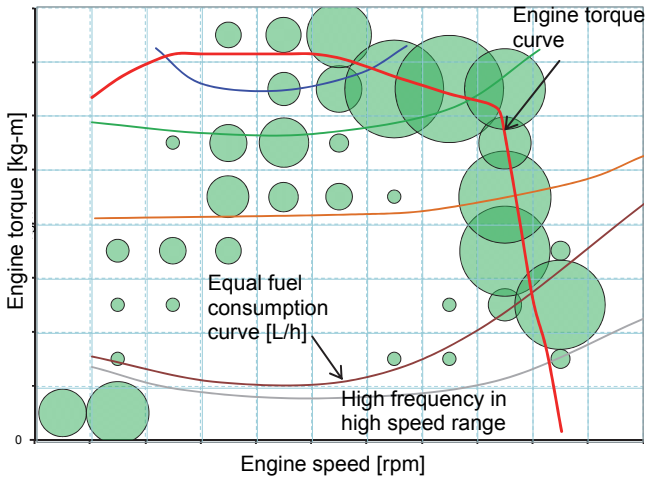


Fig. 9 Comparison of fuel consumption on in-house standard courses

FD80-10 (Torque converter equipped vehicle)
Current model



FH80-1 (Hydrostatic transmission vehicle)
New model

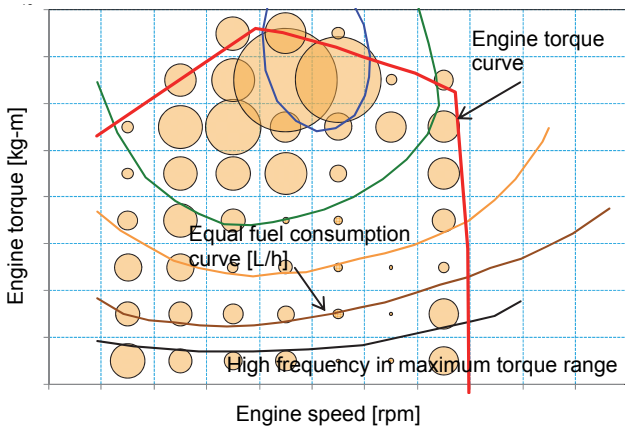


Fig. 10 Frequency distribution and fuel consumption map on high-load course

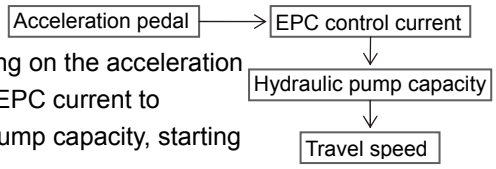
6.2 Improvement in drivability and operability

The electronically controlled hydrostatic transmission introduced in FH35/40/45/50-1 continuously controls the swash plate, allowing forward and reverse travels to be switched smoothly even stepping on the accelerator pedal without applying the brake to stop the vehicle. The transmission also produces a braking effect during the neutral swash plate position, which minimizes sliding down on slopes, reducing operator's fatigue. These benefits have gained high evaluation particularly among users in the paper industry. FH60/70/80-1 trucks, which have a similar user base, are also expected to be well-received.

Users engaged in harbor-related work have been requesting the improvement in drivability in inching travel at 0 to 0.5 km/h for higher efficiency in loading containers. The

FH60/70/80-1 has incorporated the improvement in acceleration and inching control in low speed ranges (**Fig. 11**).

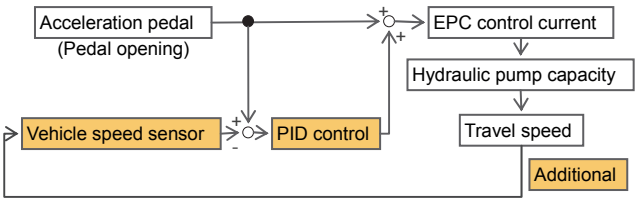
FH35 to 50-1



Slightly stepping on the acceleration pedal causes EPC current to increase the pump capacity, starting the vehicle.

On FH35/40/45/50-1, there is a delay in vehicle response during inching start, causing a delay in moving the vehicle off. As a result, operators tend to step on the accelerator pedal further, causing to start quicker. FH60/70/80-1 has employed feedback control in the inching speed range to reduce the delay in vehicle response. This has improved starting and low speed travel performances in lower speed ranges.

FH60/70/80-1 [Feedback control has been added in inching speed range only.]



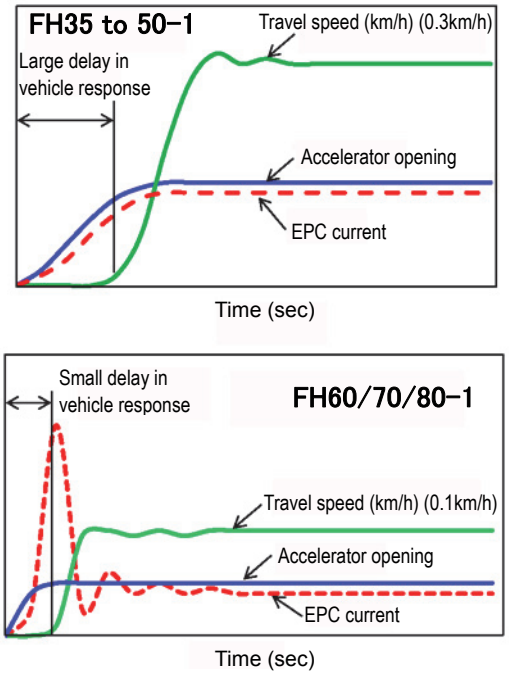


Fig. 11 Control in low speed ranges

Other improvements

- The deceleration when the accelerator pedal is released in low vehicle speed ranges has been increased so that the vehicle can be stopped only by releasing the accelerator pedal.
- The hydraulic drive power is retained during simultaneous operation (i.e. the accelerator and inching pedals are stepped on simultaneously) in inching so that the vehicle can be smoothly stopped using the mechanical brake.

These improvements have allowed for adjustment from inching start to stopping, thus dramatically improving drivability at inching speeds for container work in harbors in particular.

Since a hip support design is used in the conventional operator's seat, large operators often feel the sitting space is too tight. On FH60/70/80-1, the operator's seat has been changed to a waist support design with good hold and wider seating surface so that large operators can be seated comfortably.

Fig. 12 New operator's seat

6.3 Safety

A travel speed limit function is equipped as standard, which allows the maximum travel speed to be limited at four levels to work in a confined space or to fit the specified speed limit in a factory.

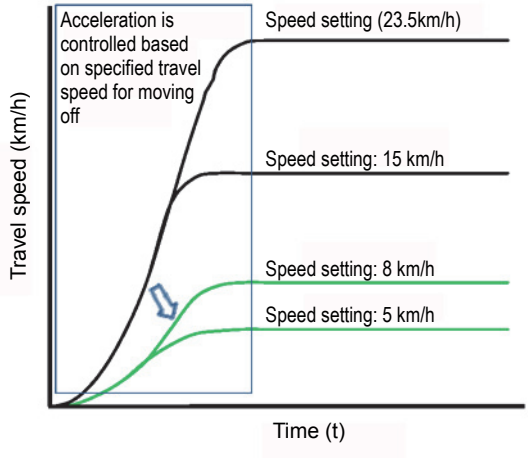


Fig. 13 Four levels of maximum speed settings

For additional safety, a seat belt switch has been added to alert the operator not wearing the seat belt.

6.4 ICT (Information and Communications Technology)

FH60/70/80-1 is equipped with 3.5-inch color LCD multi-monitor, which greatly improves the visibility of vehicle information (**Fig. 13**). In addition, a speedometer and load meter, which were optional equipment on previous models, are provided as standard for greater functionality.

FH35/40/45/50-1 models first introduced KOMTRAX as standard equipment as forklift trucks for visualization of information such as position, operating status, and fuel consumption. FH60/70/80-1 are equipped with a further improved KOMTRAX, which provides greater support for operators with information on actual operation hours and fuel consumption during that period, as well as operator identification using ID keys provided as an option.

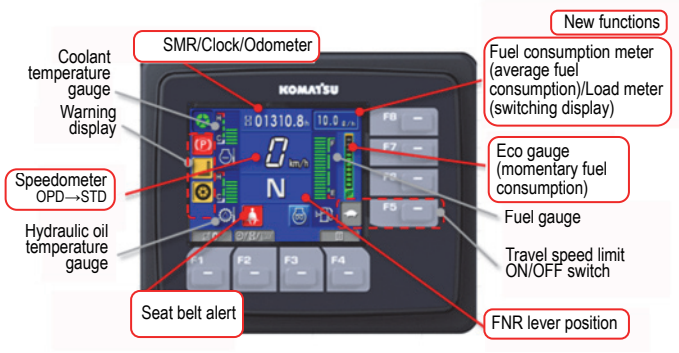


Fig. 13 Color LCD multi-monitor

7. Conclusion

FH35/40/45/50-1, equipped with a hydrostatic transmission and closed-center load sensing system, have become one of the most successful Komatsu products. With a view to expanding the lineup of the FH series into the 6-8 ton class, we have developed the FH60/70/80-1 as further advanced models with the addition of various new features. We will promote the evolution and growth of the FH series to provide attractive products that meet the needs of the market.

Introduction of the writers

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[A few words from writers]

By further improving the features of FH35/40/45/50-1 models which have been highly praised in the market, we have developed more sophisticated forklift trucks through close cooperation with other development centers, related divisions in the factory, and testing centers.

In addition, the features described in this paper have also been introduced to the 3.5-5 ton class models, and the new FH35/40/45/50-2 models that conform with Tier 4 Final have been released at the same time.

It is our pleasure if those seven models including the new FH60-1, FH70-1, and FH80-1 could contribute to the sales expansion of Komatsu forklift trucks and further satisfaction of users.