Empty Container Handling Forklift "FC70H-3" in Compliance with 4th Stage of Exhaust Emission Regulations for Non-road Diesel Special Motor Vehicles

Mitsubishi Logisnext Co., Ltd.
New Product Development Department, New Product And Component Development Division

As part of decarbonization and environmental efforts, Mitsubishi Logisnext Co., Ltd. has developed and launched vehicles that comply with the latest exhaust gas regulations. As a new development, empty container handling forklifts were adapted to run on a diesel engine compliant with the 4th Stage of Exhaust Emission Regulations for Non-road Diesel Special Motor Vehicles in Japan. The product was launched in February 2024. This report presents the characteristics of the empty container handling forklift "FC70H-3" and its safety enhancement features.

1. Introduction

Aiming to further prevent air pollution, the 4th Stage of Exhaust Emission Regulations for Non-road Diesel Special Motor Vehicles came into effect in October 2014, with the tighter standards on nitrogen oxides (hereinafter referred to as NOx) than the 3rd Stage. The regulations also introduce the use of an opacimeter for the measurement of black smoke, prescribing stricter values (**Table 1**). Our empty container handling forklift, FC70H-3, presented herein is used to handle, transfer, stack and store two types of empty containers (i.e., 20-foot and 40-foot containers specified by the International Organization for Standardization or ISO 668), mainly at empty container depots (ECD) adjacent to wharfs. When compared to the forklift trucks handling loaded containers, empty container handling forklifts are characterized by higher mobility and lower vehicle prices. Production has continued as 3rd Stage Regulations-compliant Forklifts, with the designation as motor vehicles manufactured in small numbers because Mitsubishi Logisnext Co., Ltd. sells only about 10 units annually. The development of a new engine was timed to coincide with reaching total sales of 100 units, which is the special quota for the motor vehicles thus designated. FC70H-3 with the new engine has been made available commercially since February 2024.

Table 1 Comparison list of regulatory values on exhaust gas for non-road diesel special motor vehicles

	CO (g/kWh)		NMHC (g/kWh)		NOx (g/kWh)		PM (g/kWh)		Diesel black smoke*	
	3rd Stage	4th Stage	3rd Stage	4th Stage	3rd Stage	4th Stage	3rd Stage	4th Stage	3rd Stage	4th Stage
18 kW ≤ <37 kW	5.0	Same as 3rd Stage	0.7	Same as 3rd Stage	4.0	Same as 3rd Stage	0.03	Same as 3rd Stage	25% (0.80 m^{-1})	0.5 m^{-1}
37 kW ≤ <56 kW	5.0	Same as 3rd Stage	0.7	Same as 3rd Stage	4.0	Same as 3rd Stage	0.025	Same as 3rd Stage	25% (0.80 m^{-1})	0.5 m^{-1}
56 kW ≤ <75 kW	5.0	Same as 3rd Stage	0.19	Same as 3rd Stage	3.3	0.4	0.02	Same as 3rd Stage	25% (0.80 m^{-1})	0.5 m^{-1}
75 kW ≤ <130 kW	5.0	Same as 3rd Stage	0.19	Same as 3rd Stage	3.3	0.4	0.02	Same as 3rd Stage	25% (0.80 m^{-1})	0.5 m^{-1}
130 kW ≤ <560 kW	3.5	Same as 3rd Stage	0.19	Same as 3rd Stage	2.0	0.4	0.02	Same as 3rd Stage	25% (0.80 m^{-1})	0.5 m^{-1}

* Diesel black smoke under heavy acceleration with no load is measured by a black smoke meter (3rd Stage) and an opacimeter (4th Stage).

To meet the exhaust gas regulations, a Volvo engine with a proven record for use in other large forklifts has been adopted in addition to the urea selective catalytic reduction (hereinafter referred to as SCR) system for exhaust gas purification (**Figure 1**). The 4th Stage of Exhaust Emission Regulations for Non-road Diesel Special Motor Vehicles has thus been satisfied. By making the engine auxiliary equipment and electrical control parts the same as other models, new features with higher environmental performance and work efficiency were achieved over the minimum development period. Moreover, the functions related to safety improvement were actively incorporated to enhance the safety and security required at the operation sites.

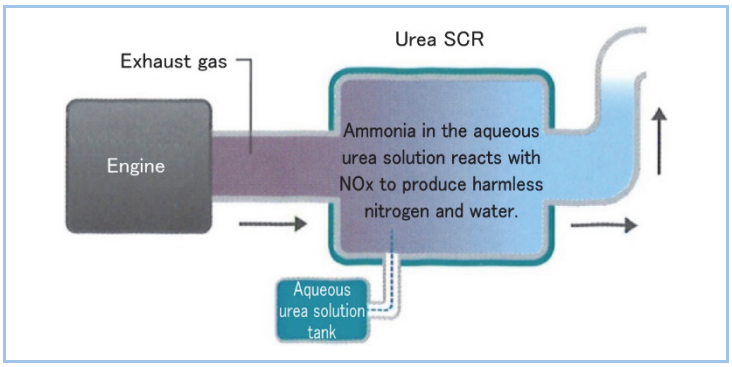

Figure 1 Urea SCR system diagram
Schematic diagram of urea SCR system.

2. Characteristics

2.1 Incorporation of urea SCR system

FC70H-3 is equipped with a urea SCR system for exhaust gas purification. NOx levels in exhaust gas are significantly reduced by allowing chemical reactions to occur using an aqueous urea solution together with a catalyst. Being simplified, the exhaust gas system has no diesel particulate filter (hereinafter referred to as DPF). This results in reduced maintenance costs (no need to replace DPF), less vehicle downtime and lower lifecycle costs.

2.2 Highest lifting speed in Japan

In upgrading the engine for compliance with the 4th Stage Regulations, we have also realized the highest lifting speed among the same classes in Japan, improving the container handling performance (**Figure 2**).

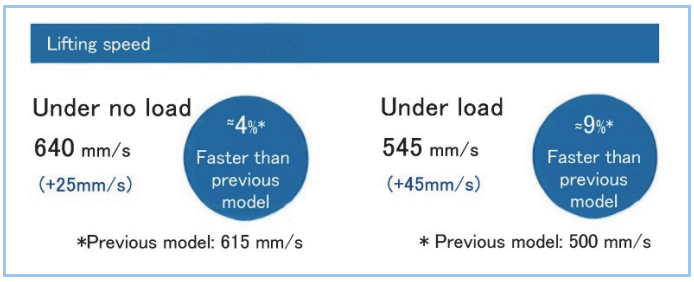

Figure 2 Lifting speed
The figure shows the degree of improvement in the lifting speed from the previous model.

2.3 Adoption of viscous fan clutch system

Conventionally, the fan coupled with the engine output shaft is rotated at the same speed as the engine to blow air to the cooling system. In FC70H-3, however, a viscous fan clutch is adopted with viscous oil between the engine output shaft and the fan. Using this viscous clutch, the flow rate of viscous oil, which is a fluid coupler, is reduced especially when the temperature of the engine cooling water is low. The resulting reduction in fan rotations compared to the number of engine revolutions reduces the load on the engine, as well as causes less wind noise during fan operation.

2.4 ECO mode function

FC70H-3 is equipped with the ECO mode as a standard function, and operating in this mode can improve the fuel efficiency by about 10% and reduce carbon dioxide (hereinafter referred to as

CO_2) emissions. In the standard mode, the degree of pressing the accelerator pedal is directly converted to the degree of accelerator opening. As shown in **Figure 3**, the ECO mode, however, controls based on the following two functions. One is accelerator opening delay, in which a cumulative upper limit is set on the change in the accelerator opening for acceleration, thereby allowing the vehicle to respond as if the pedal was pressed slowly. The other is to keep the accelerator opening smaller than the standard mode when the pedal is pressed down fully. The improved fuel efficiency and reduced CO_2 emissions have thus been achieved, while ensuring the mobility performance suitable for practical use.

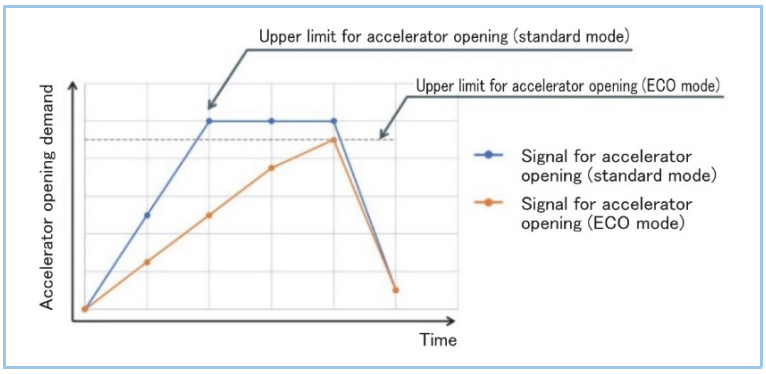

Figure 3 ECO mode function control diagram
The figure illustrates the accelerator opening demand delay control and the capped maximum degree of accelerator opening.

2.5 Addition of long wheelbase model that can handle ISO 45-foot containers

In view of further improvement of logistics efficiency and reduction of CO_2 emissions, we have added a model with a long wheelbase to our product lineup. This new model can handle 45-foot empty containers specified by ISO 668, whose use is expected to be more common. When compared to the 40-foot empty container, the 45-foot empty container is about 800 kg heavier. However, the wheelbase extended by 150 mm from the standard model enables the maintenance of the vehicle's front-rear stability ratio necessary for transportation of empty containers, ensuring that the vehicle can be operated exactly like the standard model.

3. Safety enhancement

3.1 New option of "Good Viewer" 360-degree monitoring system

As shown in **Figure 4**, a new option for operational safety assist, which has been installed in FC70H-3, enables images from four cameras attached to the front, rear and both sides of the vehicle to be processed in real time, formulating a 360-degree bird's-eye view of the entire area surrounding the vehicle as if seen from above. The formulated image is displayed on the monitor in the operator's cab. In this way, the areas that are difficult to see directly, such as ones near the furthest end of the counterweight, can be checked on the monitor.

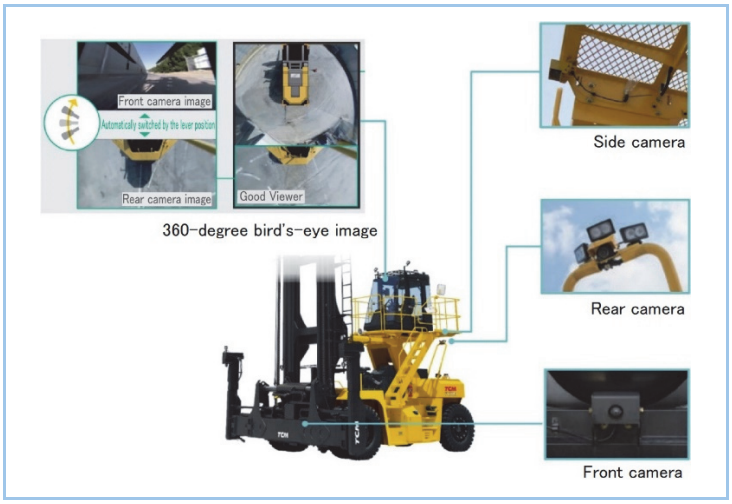

Figure 4 Good Viewer
Schematic diagram of Good Viewer system.

3.2 Adoption of liquid-crystal multifunction meter panel and display of rear tire turning angle

Unlike the previous models with an analog meter, FC70H-3 is equipped with a multifunction meter panel with a 9-inch liquid-crystal display (hereinafter referred to as LCD) at the center. The LCD screen provides information such as the traveling speed, remaining amount of aqueous urea solution, and vehicle error codes. The coordinated control has also been made possible by linking to the engine and vehicle controllers through the controller area network (CAN), thereby adding new functions such as vehicle parameter adjustment and failure diagnosis.

Moreover, it is difficult to see directly from the operator's cab how much rear tires turn inward or outward. Therefore, such turn is displayed on the LCD screen using a diamond-shaped symbol, enabling the operator seated in the cab to check it with least eye movement. Thus, another new safety function to help prevent accidents, such as steering errors leading to damage to containers, has been added (**Figure 5**).

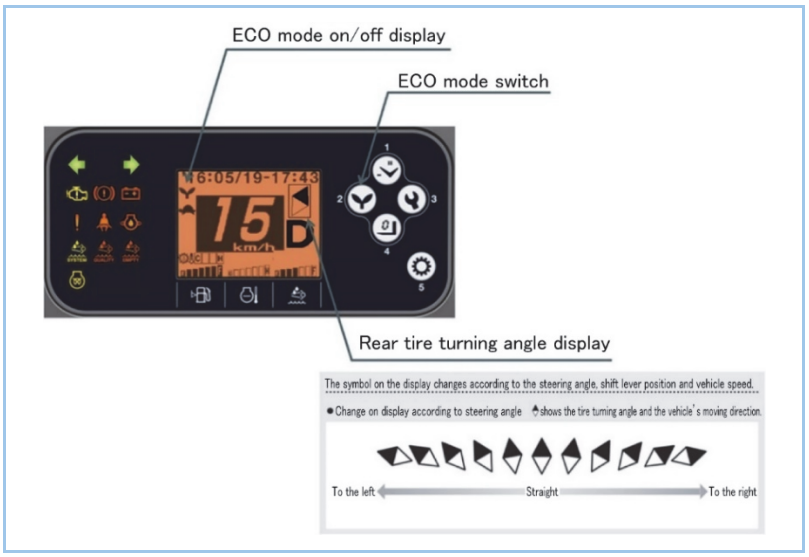

Figure 5 Liquid-crystal multifunction meter panel
The figure details how the rear tire turning angle is displayed on the LCD screen.

3.3 Adoption of SSC function to support vehicle stability while turning

The Speed Safety Control (hereinafter referred to as SSC), which is another newly added function, optimally controls the maximum vehicle speed in a manner inversely proportional to the rear tire turning angle. With this function, the maximum speed is decreased when the turning angle is large (i.e., making a sharp turn) to reduce centrifugal force on the entire vehicle including the loaded containers. Vehicle stability is thus ensured to support safe handling of containers (**Figure 6**).

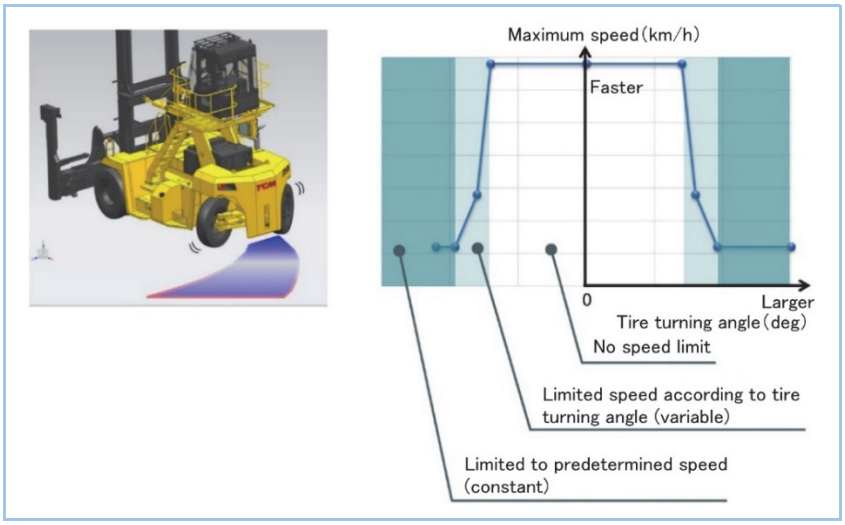

Figure 6 SSC function diagram
The figure illustrates the control of the SSC function.

3.4 Incorporation of function to keep lifting speed low

The vehicle controller detects/judges whether the vehicle is loaded or unloaded, or it is running or at a stop. As in the case of the previous models, FC70H-3 is also equipped with the function to keep the lifting speed low when running with containers loaded. Although FC70H-3 is especially required to operate with the forks lifted high for loading/unloading (e.g., as high as a stack of five containers), this function ensures the front-rear stability of the vehicle on the move and prevents sudden loss of balance.

4. Main specifications

The main specifications are given in **Table 2**.

Table 2 Main specifications

Item				Vehicle model: FC70H-3	Vehicle model: FC70H-3L Long wheelbase for 45-foot containers
Performance	Max. load capacity		kg	7,000	7,000
	Load center distance		mm	1,250	1,250
	Lift height		mm	13,000	13,000
		Under twist-lock	mm	2,300-15,300	2,300-15,300
	Lifting speed	Without load	mm/s	640	640
		With load	mm/s	545	545
	Lowering speed	With load	mm/s	550	550
	Side shift	Left or right	mm	600	600
	Mast tilt	Forward/backward	deg	4/6	4/6
	Turning circle radius		mm	5,680	5,870
	Max. travel speed	Without load	km/h	29	29
Specifications	Overall height with mast	Mast lowered (min.)	mm	8,750	8,750
		Mast extended (max.)	mm	15,750	15,750
	Height to top of overhead guard (cabin)		mm	5,200	5,200
	Overall length		mm	6,520	6,670
	Overall width, vehicle		mm	3,800	3,800
	Wheelbase		mm	4,100	4,250
	Track width	Front axle	mm	2,930	2,930
		Rear axle	mm	2,300	2,300
	Tire	Front/rear		14.00x24x24PR	14.00x24x24PR
	Vehicle weight		kg	42,310	42,430
Engine	Engine	Supplier		VOLVO	VOLVO
		Model		TAD572VE	TAD572VE
		Displacement	cc	5,130	5,130
		Output	kW / rpm	160 / 2,300	160 / 2,300
		Torque	N·m / rpm	910 / 1,450	910 / 1,450
	Exhaust aftertreatment system			Urea SCR	Urea SCR

5. Future prospect

Towards achieving a carbon-neutral society with environmental regulations, we keep updating our products to meet stricter exhaust gas regulations and electrification demand. Our line-up of high-value-added forklifts for all operations in port cargo handling, which support customers' safety and security, will be expanded to help further develop logistics and improve efficiency.