

## Introduction of Medium Size Wheel Loader in GALEO Series

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*Komatsu's line of medium size Dash 3 wheel loaders went on sale in 1993 and have enjoyed a great favor from a wide spectrum of users ever since. In order to respond to new requirements from users in the new era, however, we have decided to implement a full model change on the five leading models for the first time in eight years. The new model have recently made debut as WA380-5, WA400-5, WA430-5 WA470-5 and WA480-5 in GALEO Series which have incorporated the state-of-art technology now available in the industry.*

**Key Words:** *Wheel Loader, GALEO Series, Global Environment, Safety, IT, Tier 2 Emission Regulations, Tier 2 Noise Regulations of EU, Low Fuel Consumption Ratio, Reduction of CO<sub>2</sub> Emission, KOMTRAX 2*

### 1. Introduction

Wheel loaders have great versatility, as they are widely employed in the digging, transporting and loading of construction materials like gravel and crushed stones. That is particularly true of medium and small-sized wheel loaders which are used stockpile scooping, ground leveling and snow removing work in addition to those introduced above. The Komatsu's wheel loaders, WA Dash 3, have been highly appreciated by a wide spectrum of users since they were introduced in the markets in 1993. In the recent years, however, their relative competitive edge or merchantability has been gradually eroded by an incessant arrival of newcomers in the market one after another and their model changes. Thus there has been a strong desire from customers not only at home but also abroad that Komatsu develops a new series of wheel loaders that will meet with customers' requirements in the new era, excelling the models of competitors in Japan, the North America and Europe.

Meanwhile, people are more and more focusing on the issues of protecting the global environment and human rights on a worldwide basis. It has been a socio-economic current prevailing in the North America, Europe and Japan, as evidenced in an ever-increasing demand for stricter regulations of gas emission or reduction of CO<sub>2</sub> gas to deter warming up of the earth and lower noises.

It was against such a background that our activities for developing new wheel loaders were initiated for the first time in nine years. They were designed to be a model of high productivity that would incorporate the most advanced technology and above all give a full consideration to both the global environment and users' safety. The new products were introduced in the world markets under the brand name of WA loaders in GALEO Series. This paper discusses their basic concept, structure and features briefly. (See **Photo 1**)



**Photo 1** Appearance of WA470-5 in GALEO Series

### 2. Aim of development

At the outset of developing what was to become GALEO Series of wheel loaders later, the Komatsu’s fundamental concept for development, i.e. “Global Environment”, “Safety” and “IT”, was present to be applied across all kinds of its construction equipment. The underlying philosophy is that Komatsu’s machines in the next generation must have a long sustainable and sufficient competitive edge, and that they will well meet with the requirements of users all over the world in this new era. Guided by those development policies, while keeping it in mind to incorporate new technology as sailing points, we decided aims of the new wheel loaders as outlined in Fig. 1

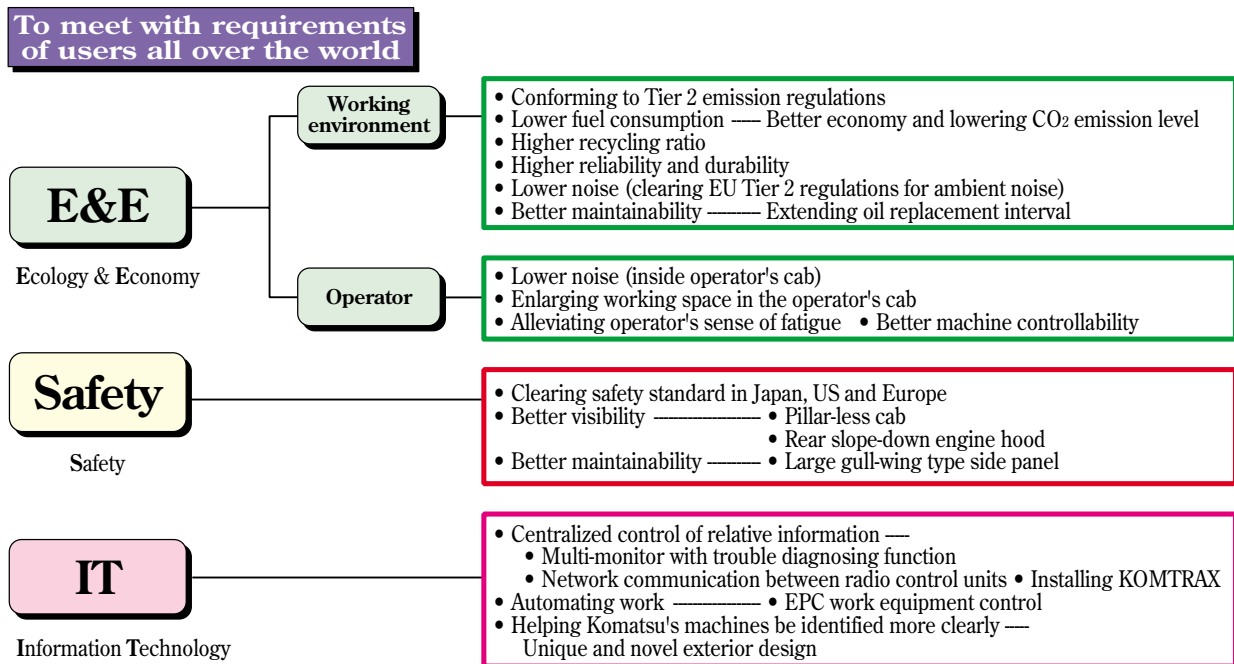


Fig. 1 Aim of development

### 3. Model lineup

A lineup of new wheel loaders was decided as shown in Fig. 2 in consideration of competition with the competitors’ models at home and abroad. Until then, the model names of medium-size equipment differed between those for the domestic market and those for the overseas markets due to a slight difference in the specifications. And a request was filed for standardizing them from within and without the company. Consequently similar model names were unified to a larger size.

In this connection, a special high-class model with what was termed “Hyper Specifications” had been sold only in the domestic market. It was powered by an engine with an electronically controlled governor and installed with tires of large diameter. At the opportunity of developing machines that conform to Tier 2 emission regulations, all these features have been incorporated into the new models and Hyper Specifications were abolished accordingly.

$\text{Machine grade} = 3\sqrt{(\text{PS} \times \text{m}^3 \times \text{ton})}$

	Conventional WA-3		GALEO WA-5	
	Japan	Overseas	Japan	Overseas
20				
21	WA350	WA380		WA380
22				WA400
23	WA400		WA430	
24		WA420		
28	WA450	WA470	WA470 (WA450 for North America)	
29		WA470M		
30				
31				WA480

Fig. 2 Corresponding relation between conventional and new wheel loaders of medium size

### 4. Major features

#### 4.1 Compatibility with global environment

##### (1) Lower fuel consumption

With the new models, we have attained dramatic fuel saving of over 15% as compared with the conventional ones. This achievement has been realized through matching an engine of high torque with a large capacity torque converter at a low speed area as well as a combination of the torque converter and a dual-speed hydraulic system in which a switch pump is cut off as interlinked with a kick-down switch.

In addition, we adopted a dual-mode select system for fuel, i.e. Power Mode and Normal Mode, to enable further fuel reduction by selecting the engine output suited to the job at hand. (See Fig. 3)

Fig. 4 and 5 show comparison of the production and fuel consumption of WA470-5 in Power Mode and in Normal Mode and comparison between WA470-5 and WA450-3 when loading on a dump truck of 10-ton capacity.

##### (2) Lower noise

In an effort to reduce the noise ambient noise generated from the machine, the first step we took was to adopt a low noise engine and to lower the rated rpm of the engine by 10%. In addition to that, we decided on adopting a variable hydraulically driven engine cooling fan system and sealing the

engine room. Those measures have remarkably reduced the ambient noise.

The engine cooling fan system we have taken up in the development this time has the following characteristics and effects.

- ① Its rotation speed is controlled according to the engine cooling water temperature, hydraulic oil temperature and transmission oil temperature, whereby the max. fan rotation speed can be lowered and therefore noise reduced, while loss of the horsepower is saved.
- ② Independent space is provided between the engine side and the fan and radiator side as a cooling room, which also serves to easily shut off the engine noise. Moreover, clearance between the fan tip and the shroud is shortened to increase the wind volume.
- ③ A fan driving hydraulic motor is neatly housed in one piece with the cooling fan. Besides, a Komatsu's unique in-fan motor structure, which enables the motor to reversely rotate the fan, has been adopted this time.
- ④ Thanks to an oil circuit selector valve provided in the fan motor, the cooling fan rotation can easily be reversed, thereby rendering cleaning of the core dramatically easy.

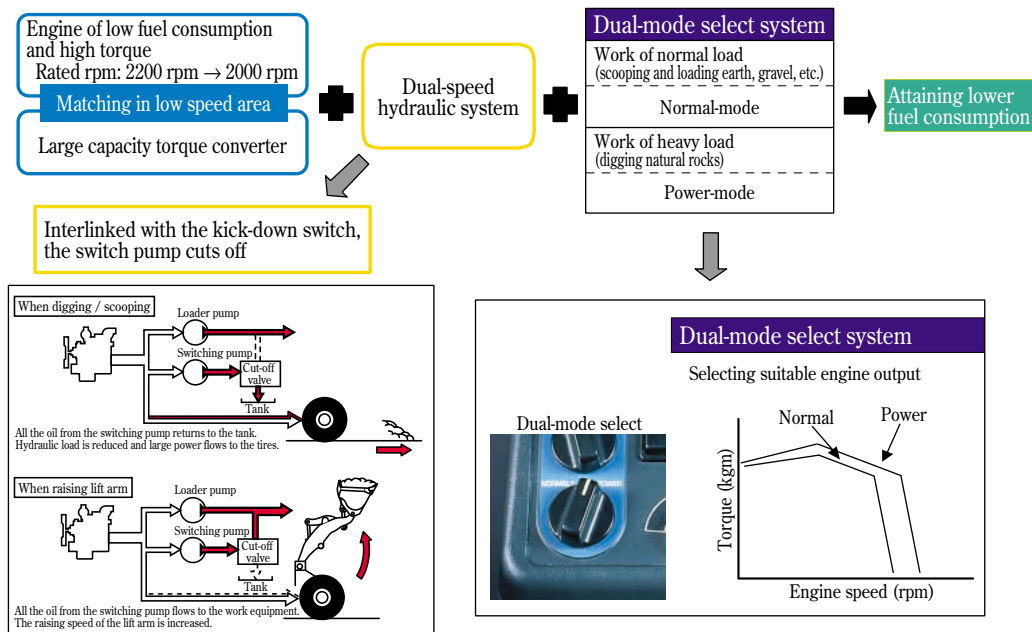


Fig. 3 Method of reducing fuel consumption

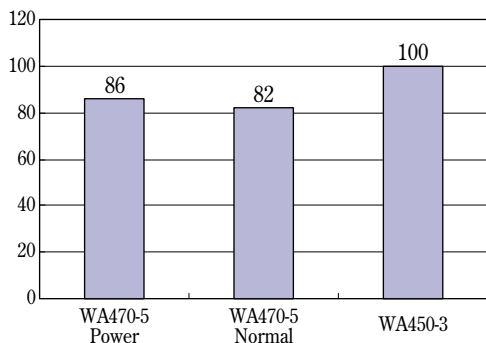


Fig. 4 Fuel consumption per unit of time l/h [%]

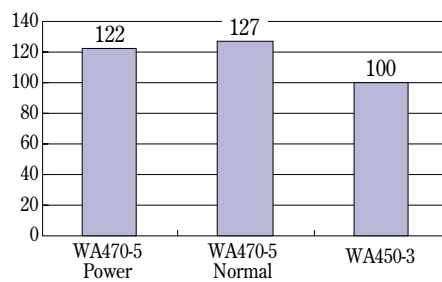


Fig. 5 Production per unit of fuel m³/l [%]

Fig. 6 and 7 show a schematic diagram of this variable hydraulically driven engine cooling fan system.

For the ambient noise, we set a target value at a level 2 dB (A) lower than specified in the new EU Tier 1 regulations, and could reach the value, which is now described on the machine label. Another assignment in this regard was to satisfy the value specified by our Ministry of Land, Infrastructure and Transport. In the past instance, we changed the machine's external appearance as a duct had to be installed at the rear in order to clear it. Table 1 shows each attained noise value according to the different specifications.

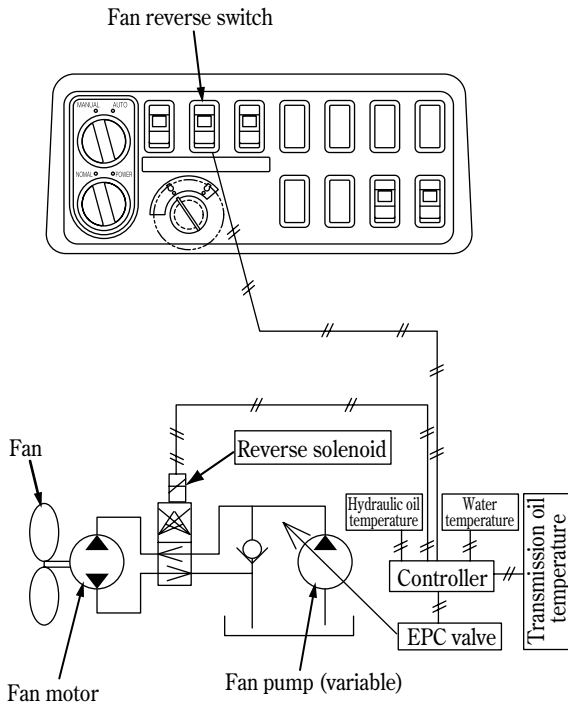


Fig. 6 Variable hydraulically driven engine cooling fan system

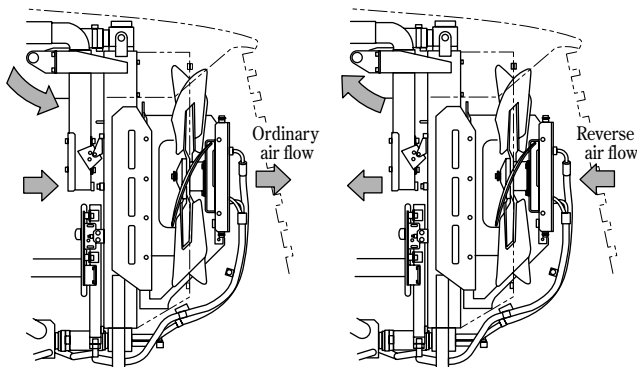


Fig. 7 In-fan motor with fan reversing function

Table 1 Ambient dynamic noise [dB (A)]

Instance of WA470-5			
GALEO WA470-5			Conventional model
Komatsu's standard specifications	Low Noise Specifications by Ministry of Land, Infrastructure and Transport, Japan	EU specifications	Komatsu's standard specifications
109	107 107*	107 110*	116

\* Regulation value

(3) Mounting engine that conforms to Tier 2 emission regulations  
 Komatsu developed a new diesel engine that conforms to Tier 2 emission regulations of EPA (Environmental Protection Agency, USA), EU and Japan's Ministry of Land, Infrastructure and Transport respectively, and we decided on mounting this new engine on the new wheel loaders in GALEO Series.

For this purpose, we mounted an engine equipped with Common Rail, a mechanism for electronically controlled high pressure fuel injection, on WA470 and WA480 wheel loader, while mounting an engine equipped with a mechanical governor with high pressure nozzles on WA380, WA400 and WA430 wheel loaders. In addition, the fuel injection timing was retarded and a highly efficient aftercooler was adopted in either of the engines. These three methods combined helped us tide over Tier 2 emission regulations. Fig. 8 shows an instance of Common Rail used in WA470 and WA480.

Each content of emission gas from the new engines was brought down to the level shown in Fig. 9 as compared with that of the conventional models when they conformed to Tier 1 regulations.

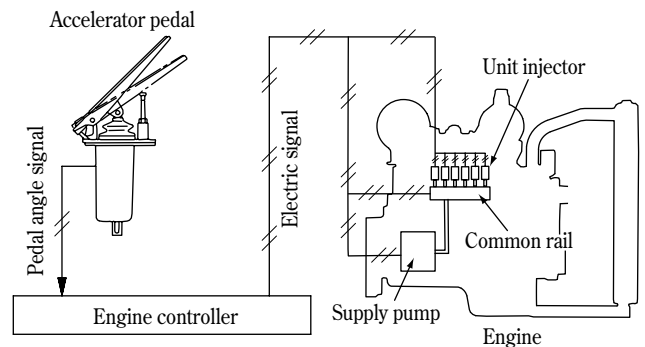


Fig. 8 Engine with Common Rail for electronically controlled fuel injection

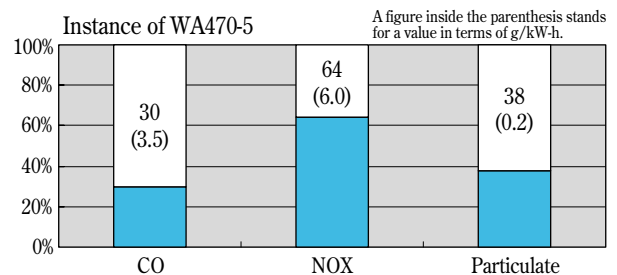


Fig. 9 Reduction ratio of emission gas content (compared with conventional model)

#### 4.2 Improving machine's comfortability and controllability

##### (1) Lowering noise at operator's ear

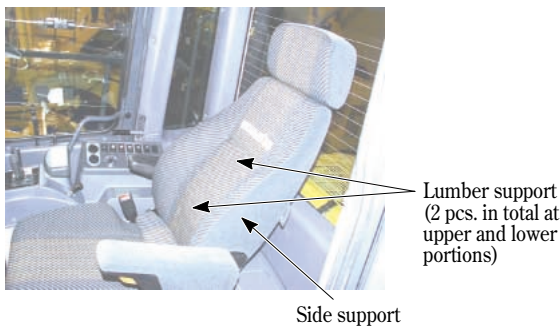
Several measures have been implemented to reduce noise at operator's ear with the result that it has gone down by approx. 5dB(A) as compared with the conventional models. They include viscous mounts for an operator's cab, rubber mounts for hydraulic piping and hydraulic valves, heightening the rigidity of the cab floor frame, shutting off noises and maintaining good air tightness of the cab room by hermetically sealing the holes on the cab floor through which the piping and wiring harnesses pass, etc. (See Table 2)

**Table 2** Noise at operator's ear

Item		WA470-5	Conventional model
Noise at operator's ear	dB(A)	71	76
Cab room air pressure characteristic	mmAq	4.5	6.0

(2) Adoption of LCAS (Lumber Care Air Suspension)

Generally a wheel loader makes an operator rapidly tired due to its characteristic that it does work while running around and at a high speed. So there has been a keen desire for upgrading an operator's seat in particular from those operators who operate a wheel loader above the medium size for a long time continuously. In order to meet with such a request, we decided on adopting the type of an operator seat that allows its lumber support and side support to be freely adjusted to the physique of an operator. For the suspension, a combination of air suspension and damper was employed so that an adequate damping effect may be obtained. (See **Photo 2**)



**Photo 2** LCAS seat

(3) Adoption of all-speed electronically modulated transmission

Another request from the users was the type of transmission that causes little shock and only short time lag in spite of frequent gearshifts for changing the travel direction or gear speed, and as such would not make an operator much tired even if operating for a long time. To respond to this request, it was decided to adopt an all-speed electronically modulated transmission that allows setting modulation at each speed independently. Moreover, the transmission is equipped with learning and control functions so that the optimum modulation may be constantly obtained even when clutch discs and other related parts wear with age.

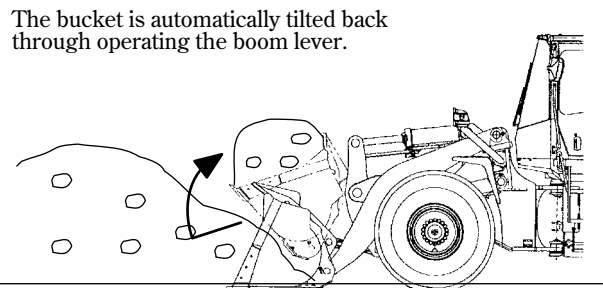
It is possible with the current Komatsu's automatic transmission to select the optimum gear speed in the range of 2nd to 4th gear speed. In the development this time, each gearshift point has been newly provided, which is intended to allow an operator to early shift the gear speed to a higher speed at as low an engine speed as possible when running on a flat ground, thereby saving fuel consumption, and to shift the gear speed at a high engine speed on an uphill slope, thereby eliminating unnecessary gearshifts.

(4) EPC (Electric Pilot Control) work equipment lever

An EPC work equipment lever has been prepared as an optional part this time, which equips the new machine with an automatic digging function. This is a device that has the

following three functions.

- ① Shock alleviating function when stopping work equipment  
The lift arm speed is slowed down right before it comes to a stop with the aim of alleviating a shock resulting from a sudden stop.
- ② Remote boom positioning function  
A boom kickout position can be freely adjusted from within the operator's cab.
- ③ Semiautomatic digging function (See **Fig. 10**)  
Bucket digging operation can be automatically carried out only by raising the boom lever, which eliminates a complex operation of the boom lever and arm lever at the same time. Now it has become easy for anyone to operate the work equipment. For the operation pattern of the work equipment, there are two modes provided depending on materials to be handled, one being a soft mode for handling loose materials and the other being a hard mode for handling crushed stones.



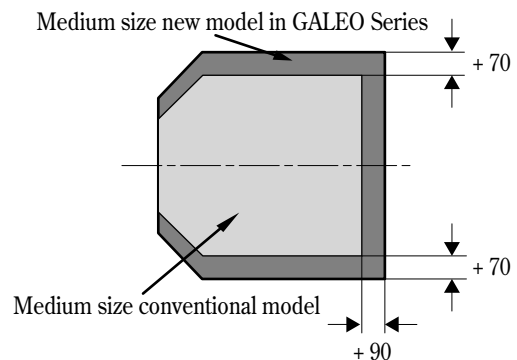
**Fig. 10** Semiautomatic digging function

**4.3 Enhancing safety**

(1) Adoption of large ROPS cab

A large ROPS cab has been selected for the new machine so that the cab provides working space wide enough for a big operator to operate with comfort. The cab has a floor area 25% larger than the conventional cab.

A flat front window glass and a pillar-less window structure have both improved the front visibility. Furthermore, laminated glass is used for all the windows to prevent glass fragments from flying off when the glass is broken. For ensuring better visibility in the rear direction, the rear window glass has a windshield defroster that will easily remove condensation and frost. (See **Fig. 11**)



**Fig. 11** Larger size operator's cab

(2) Easy-to-get on and off rear-hinged open cab door

A rear-hinged open cab door has been adopted, resulting from mounting a larger operator's cab. This is because it is difficult to open the door with a larger cab due to the limited space of the sidestep unlike the conventional cab whose door is opened after climbing on the sidestep. This structure allows an operator to climb in the cab direct from the ladder, and large space is obtained at the doorway. Besides, the ladder can have a large inclination. All these improvements assure an easy access to the cab room. (See **Photo 3**)



**Photo 3** Easy access to cab room

**4.4 Incorporating IT**

(1) Adoption of EMMS (Equipment Management Monitoring System)

The new monitor panel is installed with a troubleshooting function and maintenance management function. Thanks to them, a failure code and the machine's maintenance history is shown in the character display below the center of the main monitor, when a failure occurs.

(2) Installation of load meter

A liquid crystal display is provided in the center of the main monitor and it displays a load meter. The main monitor is such a compact device that it does not block the front view and boasts its high precision. It has now become part of the standard specifications for WA380-5 and WA430-5 wheel loaders that are destined for the Japan's domestic market, as they are mainly used for loading a stockpile.

(3) Installation of KOMTRAX 2

This is a radio control unit installed on machine which has realized transmission from the machine of information like the present location of the machine, service meter reading, failure code, etc. A receiving party can have an easy access to the information while being seated in an office. Medium size wheel loaders are equipped with KOMTRAX 2 as part of the standard specifications. This machine management system realizes the following merits.

- ① A quick response to a call for technical service in made possible in that a machine's working conditions, failure conditions, etc. are grasped, being far away from the machine.
- ② It helps boost the resale price of traded-in machines, because the maintenance history and operation history of a specific machine are correctly grasped and managed.

As the database further builds up and their analysis continues, KOMTRAX 2 will help Komatsu position itself in a more competitive place in the race of construction equipment business from now on.

**4.5 Excellent productivity**

In this section of introducing the new features, we want to take up ASD (Anti-Slip Differential or more commonly termed LSD, a limited slip differential) which has become part of the standard specifications of WA470-5 and WA480-5 wheel loaders destined for the Japan's domestic market and a lock-up torque converter which has been newly prepared as an option, starting with Dash 5.

(1) ASD

A Komatsu's axle with a built-in ASD is so designed as to prevent a wheel on one side from slipping until the difference in resistance between the left and right wheels reaches approx. 2.6 times. Thanks to this design, the wheels are saved from slipping on the ground where load imbalance between the wheels of both sides is easily invited such as soft, sandy, wet or irregular ground. Not only that, ASD is effective with prevention of tire cut and retarding wear as compared with as conventional axle. Furthermore, when there is no tire slip, practical wheel driving force will increase that much, which in turn leads to better bucket scooping.

**Fig. 12** shows the effect of ASD in terms of slip rate of the left and right wheels. The data here were obtained through a field test using wheel loaders with and without ASD respectively.

Condition of running road surface	Dry		Wet	
	Digging	Dozing	Digging	Dozing
Without ASD	43	76	43	100
With ASD	7	8	7	4

- [Remarks] 1. WA470-5 machines were used for the test.  
 2. A material handled for the test was #40 crushed stone.  
 3. The wet road surface condition was due to water.  
 4. The values shown are indices with dozing on the wet surface as 100.
- $$\text{Slip Rate} = | (r - l) / (r + l) |$$
- r = right tire turn angle, l = left tire turn angle

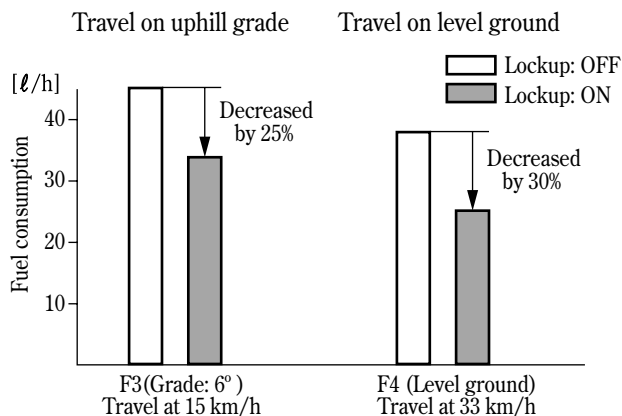
**Fig. 12** Effect of ASD (Comparison of slip rate of left and right wheels)



## (2) Lock-up torque converter

Generally there is a strong request for speedup in an uphill slope and saving fuel consumption particularly from users who travel the machines at a high speed for load and carry work or moving from one worksite to another. To cater to such requests, a lock-up torque converter has been mounted on the wheel loaders in GALEO Series of medium size for the first time. It demonstrates a marked excellence over the Komatsu's conventional models as well as the competitive models in a travel speed in an uphill slope and fuel consumption in normal running, as both of them have been largely improved.

The lock-up device is automatically actuated when the machine exceeds the specified speed limit in the 3rd and 4th gear speeds. **Fig. 13** shows a fuel saving effect attained in running with and without the lock-up device.



**Fig. 13** Effect of lock-up torque converter

## 4.6 Enhancing reliability and durability

In an effort to ever enhance the reliability and durability of each component in the power train, mainframe, wiring harnesses and hydraulic piping, we have conducted an extensive and in-depth survey and technical review, beginning at a very early stage of the development activities this time. A plan for improvement was worked out based on the findings, which were then incorporated into the new machines. However, it is a regret that we cannot touch upon them here, since they are too big a theme for this paper to handle within its limited scope.

## 5. Conclusion

Before starting with the development (large-scale model change of our medium size wheel loaders) this time, a number of restrictive conditions stood before us. To name a few, conforming to the Tier 2 emission regulations in time for the deadline, meeting with demands from the overseas subsidiaries for speeding up the technology transfer to quickly ramp up their local production and designing by means of 3D-CAD with which we had been hardly familiar at least at the time of starting this project. Indeed we have been fortunate that we could tide them over, while overcoming other various problems and hardships like a reshuffle of the staff members and a change of the working place that happened in the course of the development, and finally close the development activities with success. They have brought home to us concerned how important a good communication is for the success.

### Introduction of the writers



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### [A few words from the writers]

What largely differed in the development this time from the preceding ones was that the production of new wheel loaders had to be ramped up almost at the same speed between the domestic and foreign plants. Since the new machines were intended for the Japan's domestic market and foreign markets alike, we started at an early stage of product planning to sound out foreign subsidiaries, namely Komatsu Hanomag AG (KOHAG) in Europe and Komatsu America Corp. (KAC) in the US, over their requirements regarding marketing and after-sales service, not to mention listening in to the opinions in the domestic market. It was part of the essential efforts to have the new machines accepted worldwide.

Originally this project was initiated in the Komatsu's domestic subsidiary in Kawagoe City, then transferred to Oyama Plant and handed over to Awazu Plant thereafter. It cannot be denied that such a change necessarily triggered frictions among those concerned due to differences in the opinions partly rooted in the difference of culture they harbored. But it is true to the same extent that the frictions have served as a catalyst to stimulate themselves into a self-development in competition with each other, which in turn generated a new idea and vigor.

A dream and enthusiasm of those related to the development in Japan, the US and Europe are embodied in the newly born medium size wheel loaders in GALEO Series.