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Development of Advanced Asphalt Finisher

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Abstract

More than half a century has passed since the asphalt finisher was developed. Over the years since that time, this machine has been made larger and the performance of its various parts has been improved, but its image as a complicated machine requiring many special skilled operators has not changed.

The purpose of this paper is our development of an asphalt finisher in which the operations that required the experience and intuition of skilled operators in the past are performed automatically by various types of sensor and computers, creating a high value added machine which eliminates the previous three D's (difficult, dirty, dangerous) image of the typical construction machine and in its place creates a new three C's (clean, comfortable, creative) image while at the same time possessing the qualities of a user friendly machine through the use of robotics.

1. INTRODUCTION

The building of Japan's social capital is steadily advancing and the building of roads is also progressing steadily. Under the current conditions, the age of experienced personnel for the ever increasing road paving work is advancing. At the same time, there are fewer and fewer people who are skilled at this work, and this problem is complicated by the general shortage of labor. At the same time, workers are expressing the desire to be free from hard and dangerous labor and have an improved working environment. Under the circumstances, we established the following development concepts:

1) A machine with a man-machine interface, i.e. a machine which can be operated easily like a passenger car.
2) Highly automated machine eliminating troublesome jobs and saving skilled workers.
3) The machine should harmonize not only with the working environment but also with the social environment.
4) The machine allows an operator to be creative in doing his job.

With the above development concepts, we set out to develop a next generation asphalt finisher which uses various sensors, memory cards and computers, mounted a cabin, increased its moving speed, incorporated 4WD and 4WS, and other high technology systems. The following pages describe the method we used.

2. AUTOMATION METHOD

The initial setting of the machine before laying asphalt mixture, measurement and adjustment of paving thickness accounting for most of operatins during laying, and supply of paving materials at the front of the screed, all of which had previously been considered to be done through the human judgment of experienced operators, have been automated through the use of sensors and computers.

2-1 Machine Initial Settings

The attack angle of a screed, plane difference and other settings were previously made based on the instinct of skilled operators. Through the use of memory card, not only is it possible to make these settings automatically, but the correct screed surface pressure, crown volume and pivot cylinder position can be obtained automatically.

Through a microcomputer, the paving material thickness and width, crown equipment and finishing speed are input to the memory card. This card is then inserted into the card slot and a series of machine settings is accomplished automatically. A concept diagram and control block diagram are shown below. (Figure 1, Figure 2)

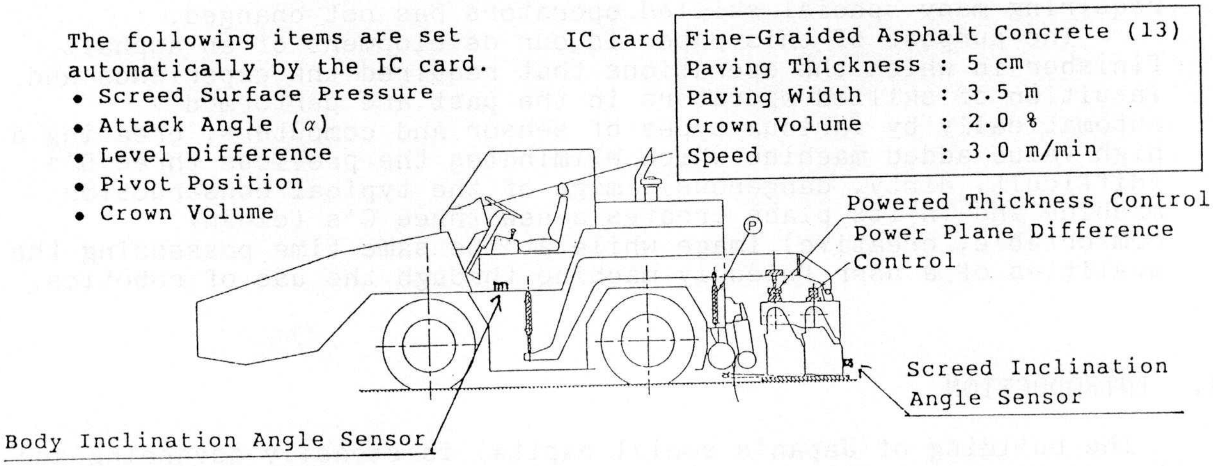


Figure 1 Concept Drawing of Initial Automatic Settings

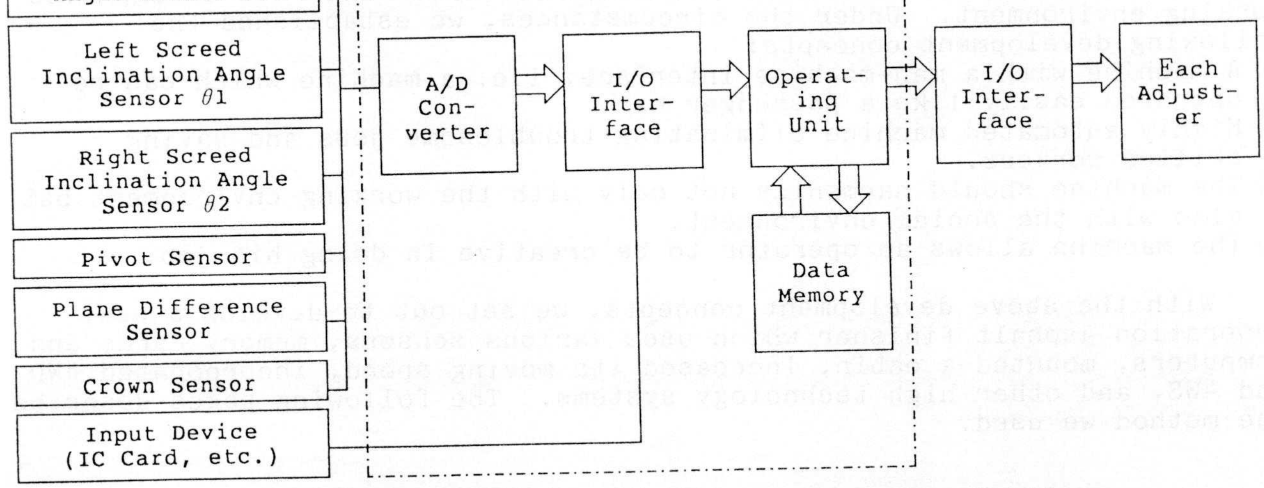
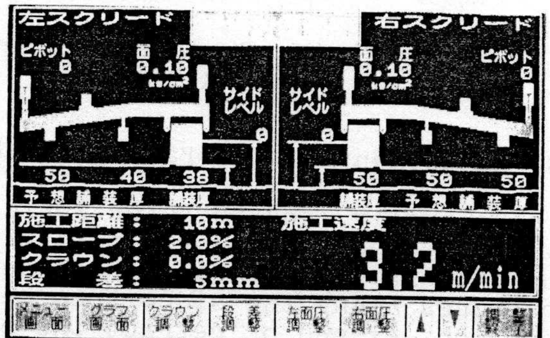


Figure 2 Block Diagram of Initial Automatic Settings

2-2 Setting the Pavement Thickness and Estimated Pavement Thickness

In the past, a measuring device known as a depth gauge was used. The operator would insert the gauge stick into the pavement and measure. This has been replaced by a contactless measuring system which simultaneously displays the depth digitally for the operator and also displays a graph of the transition in the pavement thickness.

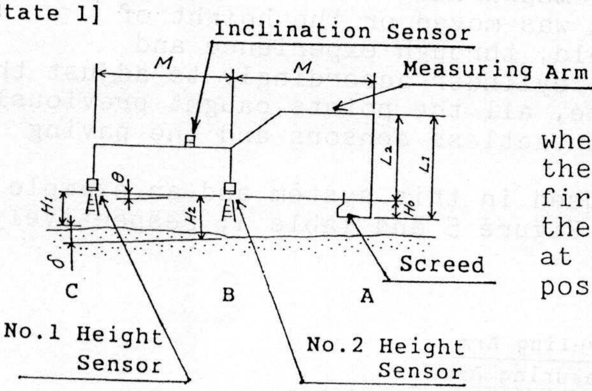
In addition, it was difficult in the past to know how the pavement thickness would change over time, but with the new machine, sensors are used to determine automatically the condition of the base course which is being paved as well as movements of the screed and display an estimated pavement thickness. These data are displayed in real time on a color display at the control panel, as shown in Picture 1.



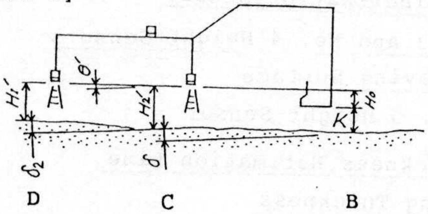
The layout diagram of paving thickness measuring device and a block diagram are shown in Figure 3 and Figure 4.

The theory used for measuring the pavement thickness is as shown below.

[State 1]



[State 2]



To measure the paving thickness T when the screed is in position B (when the machine position is in state 2), first measure the difference δ between the valleys and peaks in the base course at points B and C with the machine position in state 1.

Since $H1 + \delta = H_2 + M \tan\theta$,

$$\delta = H_2 - H1 + M \tan\theta.$$

In the right figure, the formula is given below.

$$H_2' + \delta = H_0 + T + T \tan\theta'$$

According to this formula, the paving thickness at point B can be calculated to be

$$T = H_2' + \delta - M \tan\theta' - H_0$$

(δ: Determined from the previous formula)

Furthermore, at this time, since δ_2 is measured and calculated as shown in the above figure, if the screed is moved to point C, next time it will be possible to measure and calculate the pavement thickness at point C.

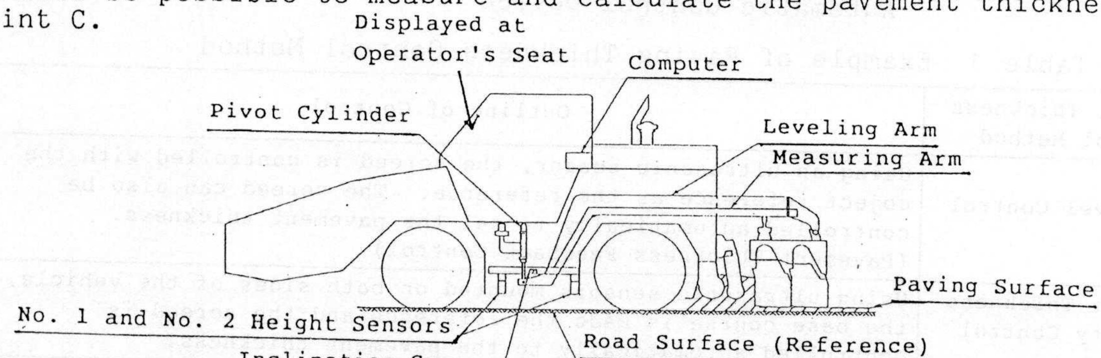


Figure 3 Layout of Pavement Thickness Measuring and Display Device

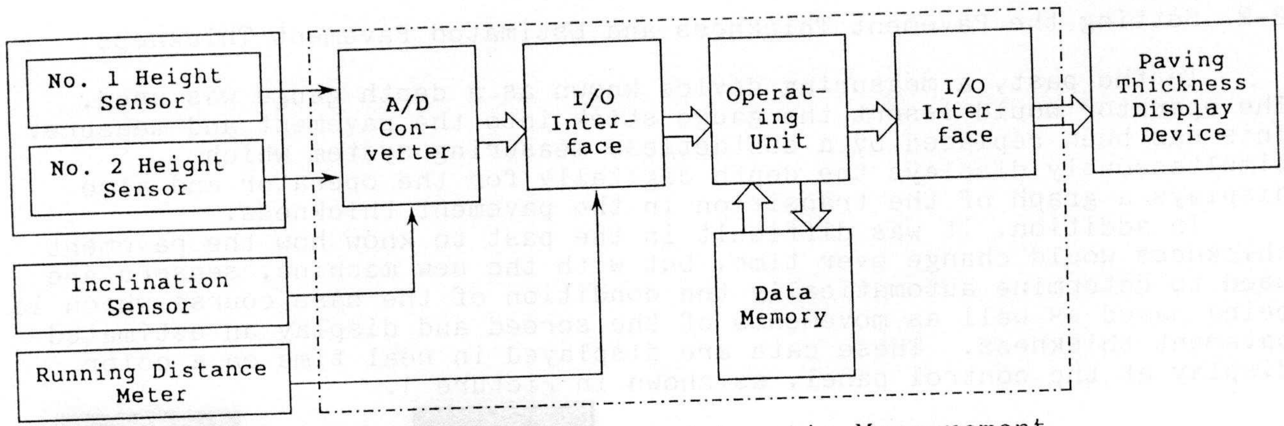


Figure 4 Pavement Thickness Automatic Measurement and Display

2-3 Adjustment of the Paving Thickness

Generally, the operator would use a gauge stick and measure the paving thickness and would take visual measurements of the amount of ground clearance of the screed when it was moved or the height of structures along the side, then he would, through experience and intuition, extend or retract the pivot cylinder accordingly to adjust the paving thickness. With the new machine, all the points caught previously by the operator's eye are caught by contactless sensors and the paving thickness is adjusted automatically.

A layout diagram of the devices used in this system and an example of the controls involved are shown in Figure 5 and Table 1, respectively.

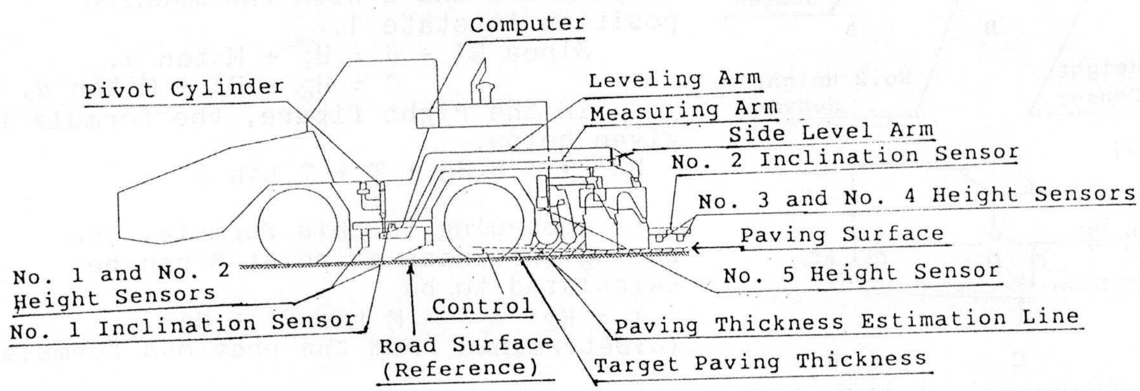


Figure 5 Layout Diagram of Paving Thickness Automatic Control Device

Table 1 Example of Paving Thickness Control Method

Pavement Thickness Control Method	Outline of Control
Side Level Control	Using an ultrasonic sensor, the screed is controlled with the object reference as the reference. The screed can also be controlled automatically to set the pavement thickness. (Pavement Thickness Feedback Control)
Pavement Thickness Priority Control	Using ultrasonic sensors mounted on both sides of the vehicle, the base course is made the reference and the screed is controlled automatically to the pavement thickness.
Slope Control	The screed's slope is controlled automatically to the set cross slope using inclination sensors.

Block diagrams of pavement thickness priority control and side level control are shown in Figure 6 and Figure 7.

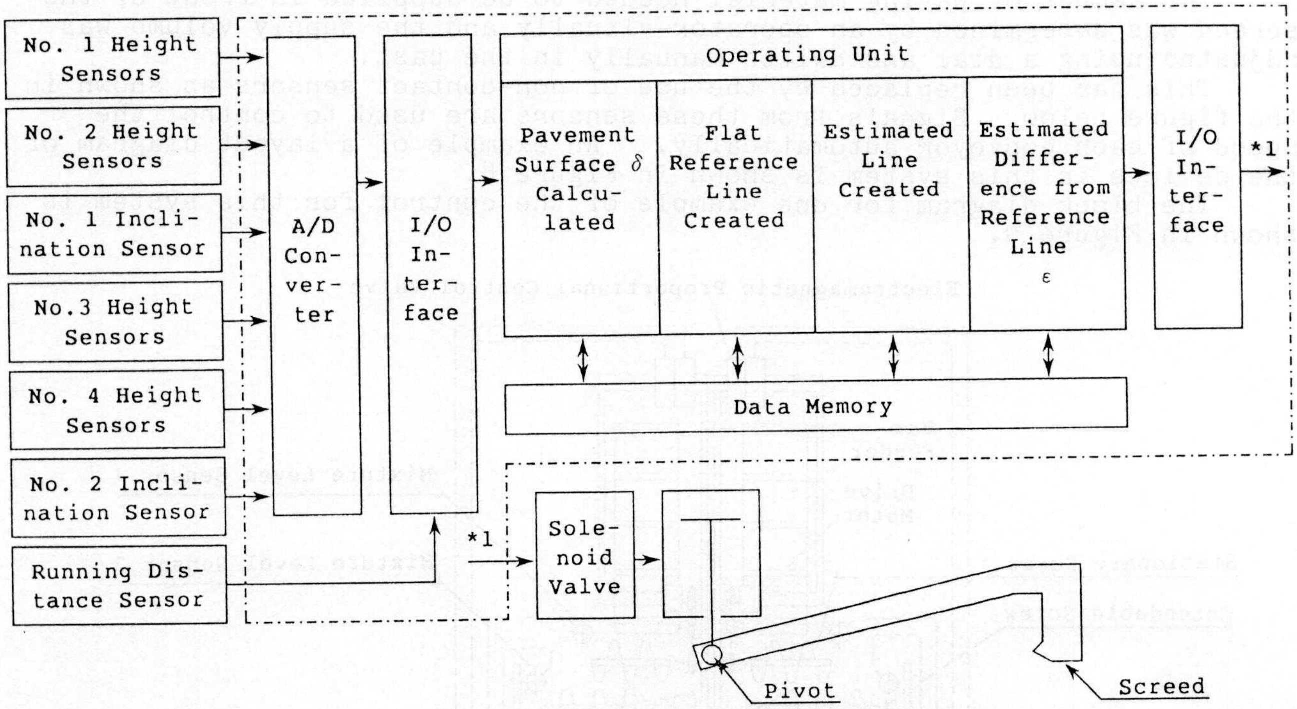


Figure 6 Block Diagram of Pavement Thickness Priority Control

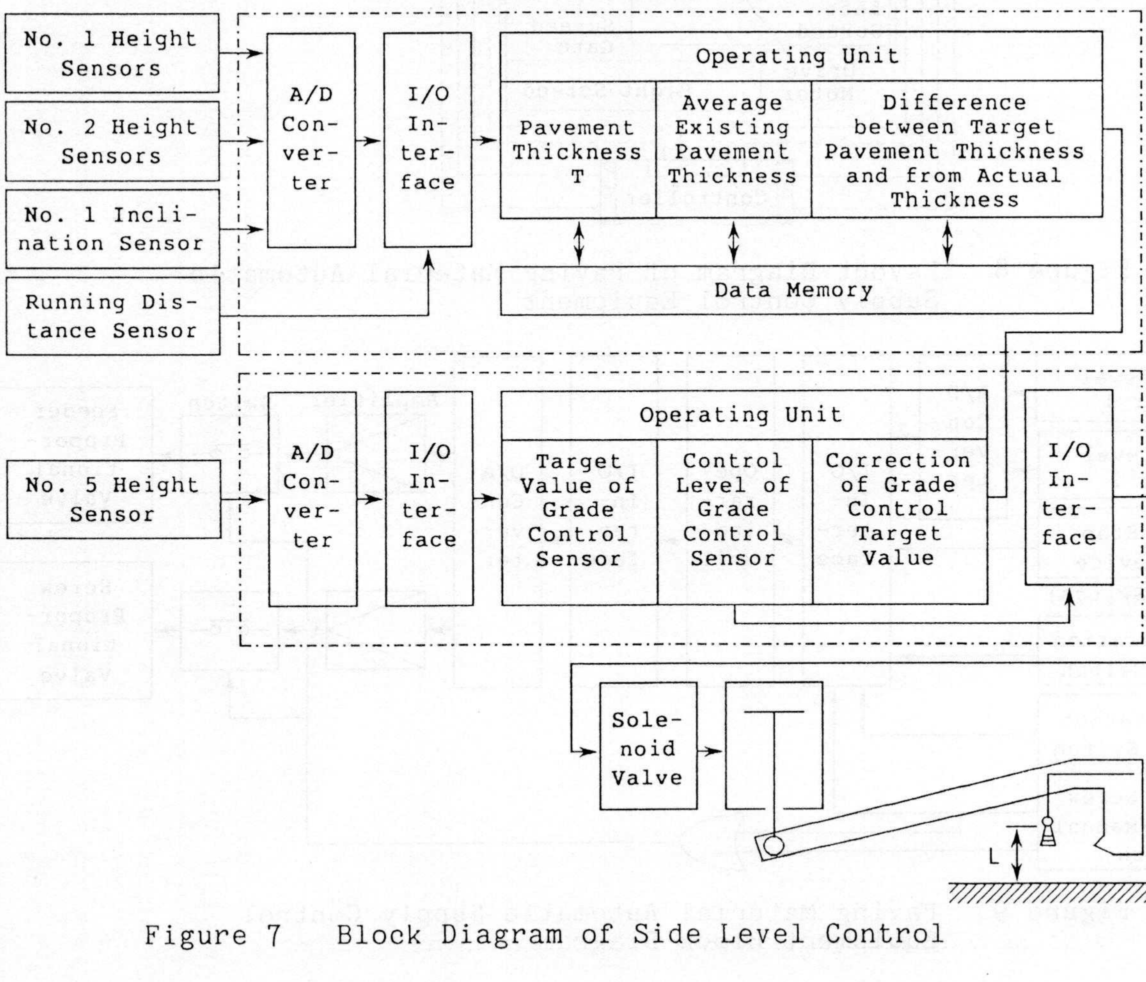


Figure 7 Block Diagram of Side Level Control

2-4 Supply of Paving Material

The amount of paving material needed to be supplied in front of the screed was determined by an operator visually and the supply volume was adjusted using a dial and switch manually in the past.

This has been replaced by the use of non-contact sensors as shown in the figure below. Signals from these sensors are used to control the speed of each conveyor automatically. An example of a layout diagram of the devices in this system is shown in Figure 8.

The block diagram for one example of the control for this system is shown in Figure 9.

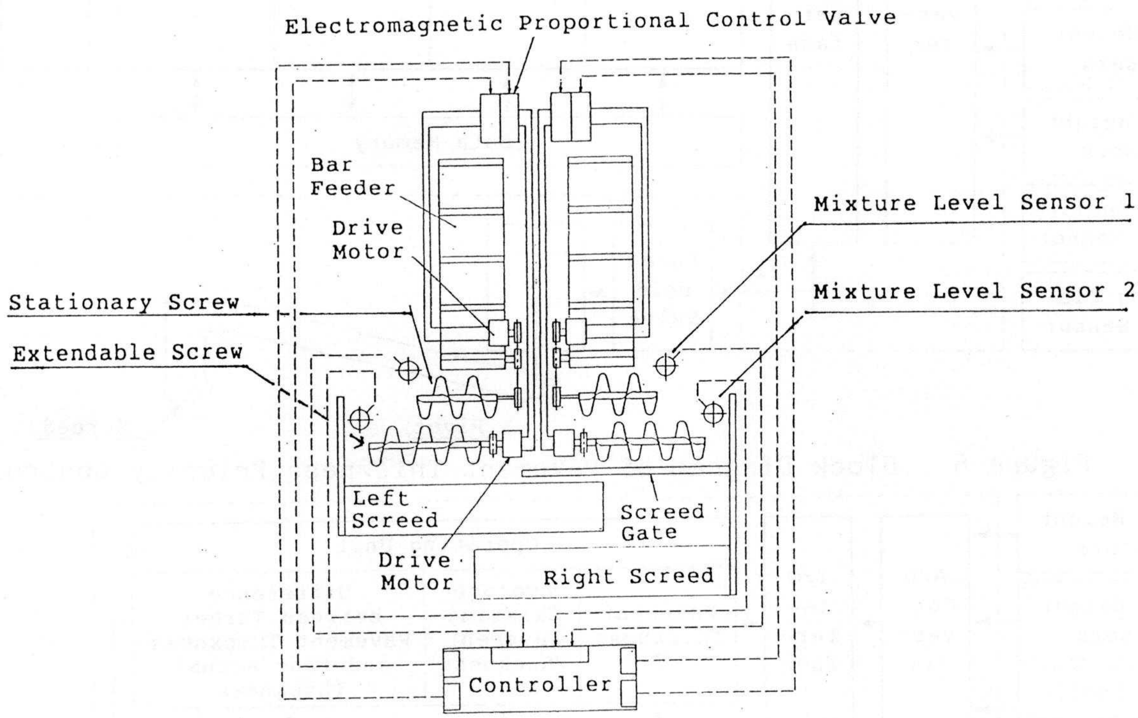


Figure 8 Layout Diagram of Paving Material Automatic Supply Control Equipment

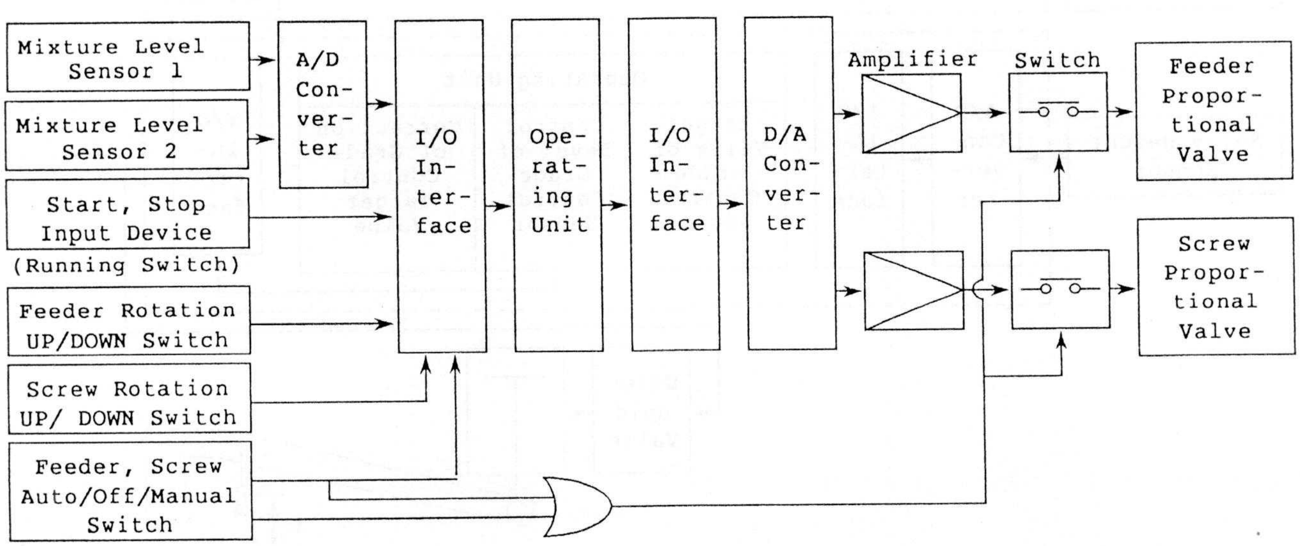


Figure 9 Paving Material Automatic Supply Control Equipment Block Diagram

2-5 Screed Heater Temperature Adjustment

In the past, the combustion system was the direct firing type, which was controlled manually by the operator. However, with new system, by setting the temperature in accordance with the working conditions, the temperature of screed is maintained at a constant level automatically. Also a hot air fan heater system is used so that paved surface texture is improved, heating is made constant and power and energy are saved. A diagram of this system is shown in Figure 10.

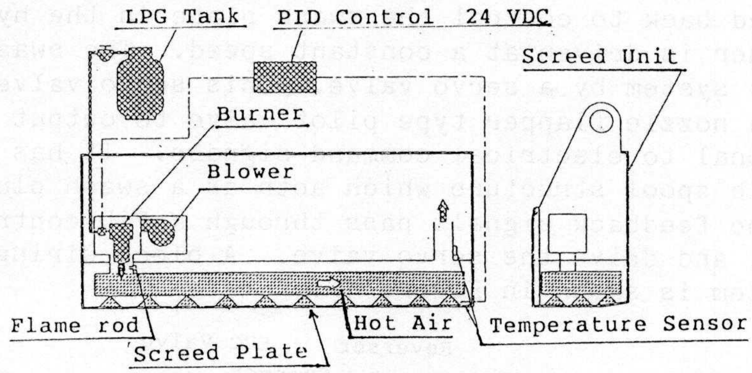


Figure 10 Automatic Temperature Control and Hot Air Screed Heater System Diagram

3. DRIVE SYSTEM

3-1 Suspension

One measure taken to harmonize the asphalt finisher with the environment was to raise the maximum speed from the previous 16 km/h to approximately 40 km/h.

To do this, it was necessary to provide the machine with riding comfort comparable with a passenger car, so a hydropneumatic suspension was adopted. A hydropneumatic suspension consists of hydraulic cylinders, accumulators, shut-off valves, check valves and other devices. The vibrations from the road surface are absorbed by the accumulators. A diagram of this system is shown in Figure 11.

This suspension system is constructed so that its functions can be rendered inactive during paving operations. And at the same time, in order to make it easier to receive material from dump truck, the machine's height is made adjustable.

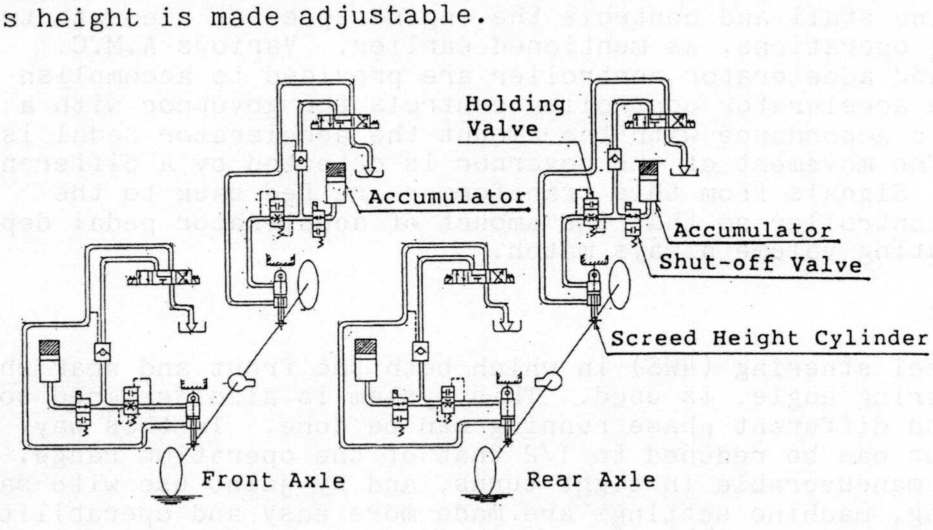


Figure 11 Suspension System Diagram

3-2 Running Speed Control

The asphalt finisher has two modes of running. One is for driving the machine and the other is for paving operations. In paving operations, the engine speed is controlled at a constant level by an electronic governor. The running speed is sensed by a proximity sensor which counts the number of gear teeth on a gear mounted on the hydraulic motor used to drive the asphalt finisher during running. Signals from this sensor are fed back to control the swash plate in the hydraulic pump so that the finisher is driven at a constant speed. The swash plate is controlled in this system by a servo valve. This servo valve has a first stage which uses a nozzle flapper type pilot valve to output pilot pressure proportional to electrical command signals. It has a second stage with a double spool structure which acts as a swash plate angle control valve. The feedback signals pass through a PID controller and current amplifier, and drive the servo valve. A block wiring diagram of the operation system is shown in Figure 12.

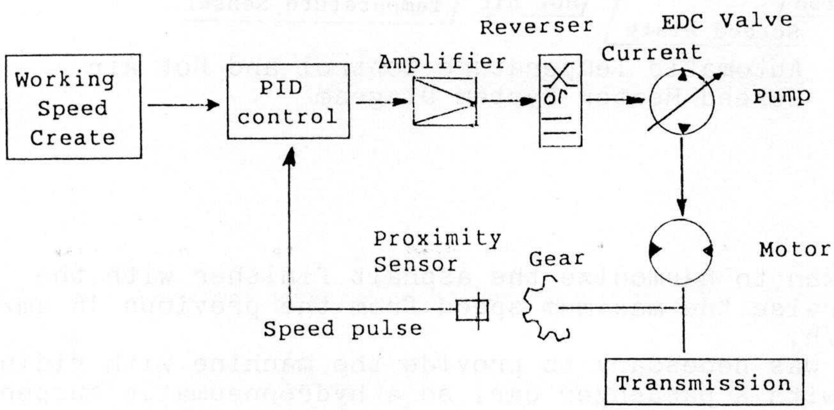


Figure 12

Here, we would like to explain a little about the electronic governor. This governor controls both the engine speed and the pump discharge volume in accordance with the amount that the accelerator pedal is depressed, realizing A.M.C. control (AutoMotive Control). This system prevents engine stall and controls the engine speed at a constant level during paving operations, as mentioned earlier. Various A.M.C. controllers and accelerator controller are provided to accomplish this control. The accelerator controller controls the governor with a DC servo motor in accordance with the amount the accelerator pedal is depressed. The movement of the governor is detected by a differential transformer. Signals from this transformer are fed back to the accelerator controller so that the amount of accelerator pedal depression and the operating volume always match.

3-3 Steering

Four wheel steering (4WS) in which both the front and rear wheels form the steering angle, is used. This system is also designed so that same phase and different phase running can be done. In this way, the turning radius can be reduced to 1/2 that of the operation range, making it extremely maneuverable in tight turns, and by joint use with same phase steering, machine settings are made more easy and operability is improved.

A diagram of this system is shown in Figure 13. (next page)

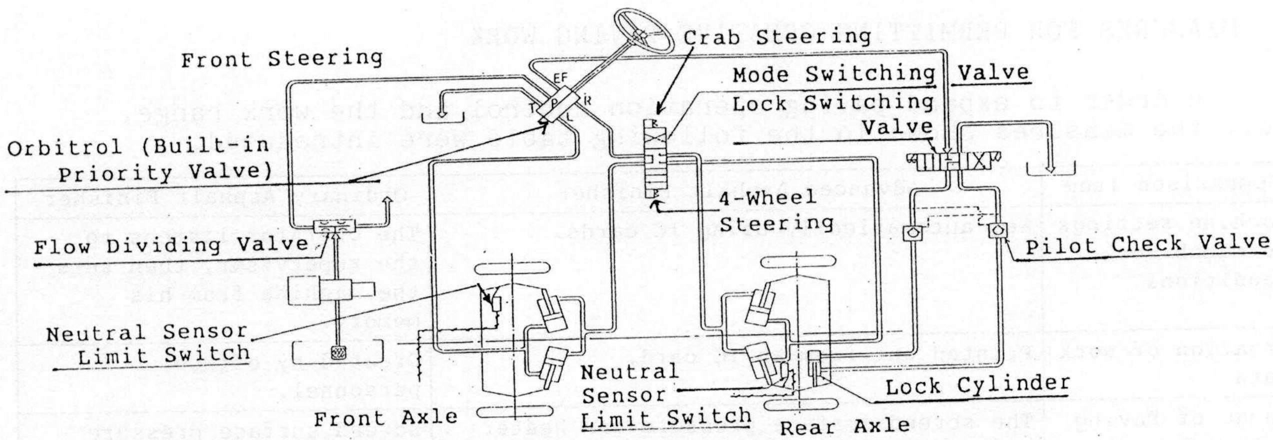


Figure 13 Steering System Diagram

4. EASY OPERATION MEASURES

In order to make it possible to operate the asphalt finisher with one operator sitting in the cabin, with no more than the senses required of a passenger car driver, the measures shown in the following table were introduced.

Comparison Item	Advanced Asphalt Finisher	Ordinary Asphalt Finisher
Driving Operation	A liquid crystal color display, touch panel, voice response, etc. minimize the number of switches and guide driving.	The user's manual must be read and memorized, and depended on in order to operate the machine.
Confirmation of dead corners, work condition	Checked from the operator's seat using a TV monitor.	Must go to the check points and check.
Communications with outside	Communications by microphone and speaker.	Direct voice communications.
Steering	Turning radius is cut in half compared to previous machines using 4WS, making machine setting easier.	2WS
Vehicle height during work and when driving	Set automatically to be low during work and high when driving.	Fixed

5. MEASURES FOR AN IMPROVED OPERATING ENVIRONMENT AND HARMONY WITH THE SOCIAL ENVIRONMENT

The measures shown in the following table were introduced particularly to banish the three D's (difficult, dirty, dangerous) image of the conventional asphalt finisher.

Comparison Item	Advanced Asphalt Finisher	Ordinary Asphalt Finisher
Cabin	Cabin included. Delux passenger car-like operator's seat, equipped with FM, AM radio, CD player, video deck, etc.	None
Lubrication, Cleaning	Cleaning is done by pressing a switch at the control panel and lubrication is done automatically.	Each part is lubricated and cleaning is done by hand.
Noise Level	Ultra-low Noise (Construction Ministry srandards)	Low Noise (Construction Ministry standards)
Design, Color	Designed to fit into an urban setting.	3D image.

6. MEASURES FOR PERMITTING CREATIVE PAVING WORK

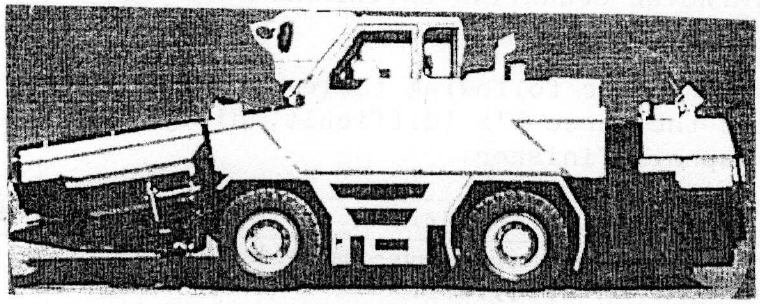
In order to expand paving operation control and the work range, etc., the measures shown in the following table were introduced.

Comparison Item	Advanced Asphalt Finisher	Ordinary Asphalt Finisher
Machine settings to match work conditions	Set automatically using IC cards.	The operator listens to the supervisor, then sets the machine from his memory.
Creation of work data	Printed out from an IC card.	Created by office personnel.
Range of Paving Material	The screed surface pressure and heater temperature can be changed freely and the range of paving materials which can be used is wide.	Screed surface pressure and heater temperature cannot be changed.

7. CONCLUSION

The integrated systems to which each of these devices has been applied were submitted to the Construction Equipment Exhibition in Kobe or '91 Kanto New Technology Fair with successful results. In addition, machines equipped with some of these devices will be developed into marketable products in the near future. In order to achieve this development, great reliance was placed on electronics technologies being developed at the present time. Therefore, it is possible that a still more advanced machine can be developed when higher precision sensors, high speed processor elements and new materials, etc. are developed.

In addition, thought is being given to the introduction of information processing functions which would carry out the collection and analysis of various types of data and linking of data from measuring operations and data from paving operations, etc. which are necessary to automation of work control. At the present time, development of some of the elements needed to further incorporate robotics into the machine is proceeding. There are also other functions being demanded by users which need to be incorporated and still more improvements are necessary. We would like to take this occasion to thank all those who cooperated with us in the development of this equipment, whether in government or private sector.



Example of Advanced Asphalt Finisher