Operation of snow work under heavy snow falling on the Highway in Niigata Prefecture JAPAN

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1 Background

1-1 Climate and Features of Japan and Niigata

The population of Japan is 126.530 million with its surface area almost equal to that of Germany or Norway, consisting of 6852 islands [1][2]. Highlands of Hokkaido and the Honshu Island have a subarctic climate, and part of the Nanpo Islands is tropical, while other regions have an extratropical climate. Therefore, Japan has significant temperature differences because of its elongated land from north to south. In addition, two-thirds of the land is mountainous, and there are small-scale basins in mountainous regions [3]. Strong seasonal winds blow from Siberia in north-western Russia along the Sea of Japan especially in the winter season. These seasonal winds contain moisture from the Sea of Japan which forms ascending currents. When these winds blow on to basins, they cause heavy snowfall.

Niigata is located at a latitude of 37 degrees north and a longitude of 139 degrees east (Figure 1), which is actually located in areas with almost the same longitude as South Andercia of Spain and Lisbon of Portugal. However, Niigata faces the Sea of Japan and therefore, it is hit by heavy snow every year. This area has an annual average cumulative amount of snow of 15.5m and has about 1.5m of snowfall per day during the peak period. With such heavy snowfall, Niigata is a popular place for ski resorts, accommodating many

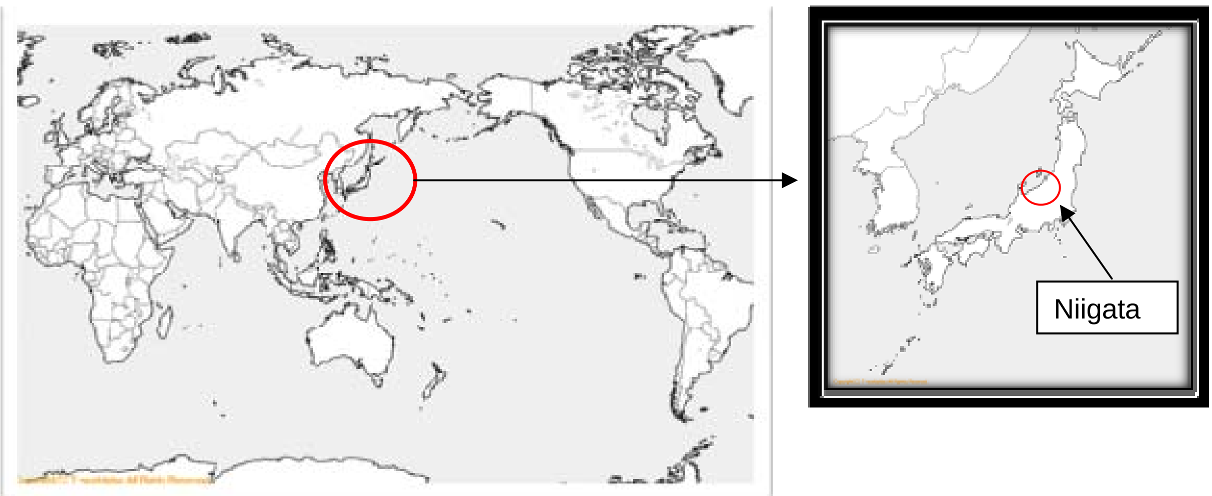

Figure 1 - Location of Japan and Niigata Pref.

people who enjoy skiing both domestically and from abroad. This results in heavy traffic in the winter season. Therefore, utilization of snow removal technology is considered to be very important to ensure safe and secure traffic networks.

１-２　Social Issues

Recently in Japan, which is characterized with such climate characteristics, there exist the following two significant social issues.

(1) Decline in Total Population

Recent social issues include the decline in the total population due to a declining birth rate and the aging of population. Declining birth rate is a situation where the domestic birth rate drops below a certain level that maintains the population constant, while the aging of population shows a situation where the percentage of elderly people (65 years old or higher) increases in the population. These social issues indicate that these different situations occur simultaneously. The population aging rate of Japan (the percentage of elderly people accounting for total population) reached 24% as of 2012, showing a growing tendency year by year [1]. Japan already moved into an aging society after only 24 years from 1970 to 1994. When Japan is compared to other countries in the world, Germany took 40 years and France took 115 years to move into such an aging society. This shows that Japan's aging rate is quite fast when viewed globally [5]. Because of these social issues, there are fewer younger labor-class generations with the increase of the elderly generation. Such an imbalance has come to light very rapidly.

Recently in Japan, the declining birth rate and the growing proportion of elderly people along with continuous job shortages have significantly decreased the younger generation in the workplace; therefore, focus has been placed on passing of extensive knowledge and know-how of skilled workers down to the younger generations in the industrial circles of Japan.

This aging issue rose to the surface in the field of road management. We especially consider that in the areas of snow and ice removal work, aging of operators of snow and ice removal vehicles and the lack of young workers will probably assume serious proportions.

(2) Electric Power Condition

The Tohoku Earthquake and resulting tsunami of Japan occurred on March 11, 2011, inflicted enormous damage to the north-east coast as shown in Figure 2 and Figure 3. In areas under the jurisdiction of Tohoku Electric Power Company, where many power plants including the Fukushima Daiichi Nuclear Power Plant were damaged, power plants capable of generating about 5,560,000 kW of electricity stopped their operation. Moreover, downpours of rain in Niigata and Fukushima at the end of July immediately after the earthquake caused other damage to hydraulic power plants in these areas, causing the power plants to shut down. This resulted in the loss of about 1,000,000 kW of electricity [7].

Within the jurisdiction of Tohoku-Electric Power Company, there is a greater need for electricity used for heating and snow melting in winter, and demand for electricity has also increased due to the reconstruction in Tohoku areas. This has necessitated the introduction of power-saving measures for electricity users and individual households. The NEXCO Group, which manages and operates highways in Japan, is also one of the electricity users and has taken appropriate power-saving measures. However, additional new measures will need to be taken.

Figure 2 - Sanriku shoreline after the earthquake

Figure 3 - Minami-Soma City after the earthquake

2 Highway Management in Winter

Highways in Japan are at the core of the national traffic infrastructure for regional exchange and coordination in Japan. These transportation routes support a wide variety of industries and leisure activities where vast amounts of people and goods are exchanged day and night. Land transportation by truck accounts for most of domestic logistics, and the intermittent of these distribution channels causes damage to the economic activities of Japan.

Snowfall and accumulated snow is one of the significant factors that cause accidents or traffic jams. Niigata is an area where the snow and ice management system operates for about six months every year. It is easy to recognize that the traffic accident rate during the snowfall period increases when compared to the other six months. If an accident happens on a highway, in many cases traffic needs to be stopped or restricted in order to prevent secondary problems from arising. In order to avoid taking such traffic restriction measures as much as possible, the NEXCO Group that manages and operates highways has been required to implement snow-resistant road maintenance and necessary safety measures for traffic. Given that, we have worked on mechanical snow removal by using snow removal vehicles and spreading anti-freezing agents. Additional measures such as snow removal equipment and road heating as well as watering for snow melting are also used. Recently, we exercise more effective winter road management by snow removal management, and road condition monitoring with prediction systems, based on the utilization of the Intelligent Transportation System (ITS).

３ Technological Development

As part of the NEXCO Group, our company, NEXCO Engineering Niigata, is a union of about 300 professional engineers that maintains and manages the highways in Niigata day and night including its extension of 430km. Concentrating expertise and know-how we accumulated through our daily work, we developed the following technologies in order to work on the above-mentioned two issues, the decline of population and electric power deficiency.

３-１ Integrated Device Controller

The progression of aging and shortages in staff that operates snow and ice removal vehicle for the NEXCO Group has continued. This has required the introduction of simplified on-board operating controllers. An integrated device controller integrates operations and the operator by converting the functions of multiple devices of a snow and ice vehicle into predetermined patterns. This makes complicated and troublesome operations easier. This integrated device controller is implemented as an additional function to the on-board GPS location management system that is described later on. Therefore, this controller can be installed if vehicles are equipped with GPS devices.

Snowplows, wet salt spray machines, and indication devices installed on snow and ice work vehicles are different and operated by different operational devices. Thanks to this integrated device controller, operations of these machines and devices have been integrated. The functions and specifications of this controller are as follows:

- Device controller as well as indicator is a touch-panel 7-inch TFT LCD monitor (Figure 4)

- Develops a certain pattern of multiple general-purpose work which is automatically controlled with simplified operations

- Guidance for the operational contents are indicated in a heads-up caption and the alarm function notifies the operator when the caption is displayed

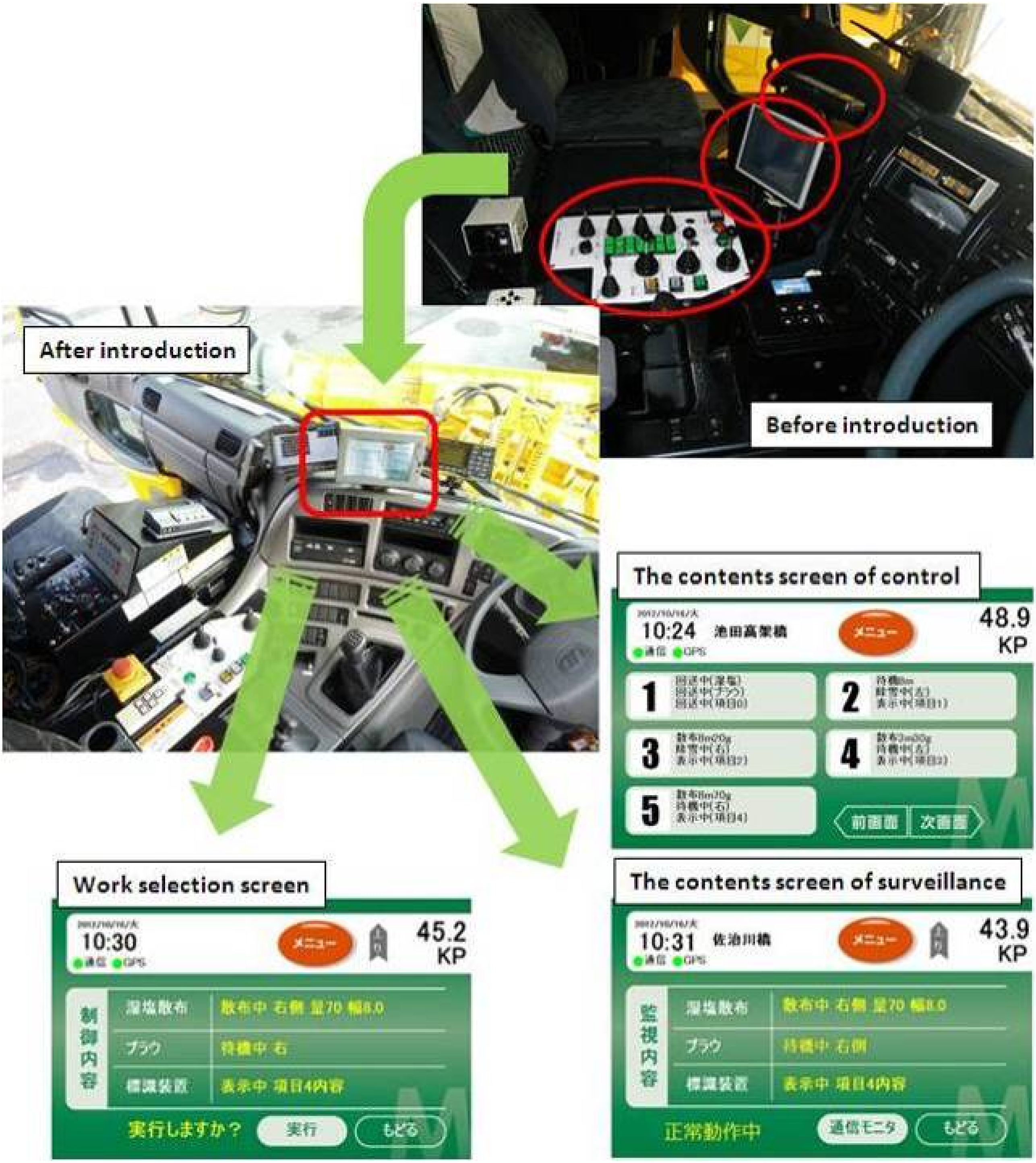

Figure 4 - Installation image of this controller in a vehicle and the screens during operations

The operation of integrated device controllers is currently on a trial basis, and they have been installed in snow and ice removal vehicles for the purpose of evaluation. When operators were asked what problems they have encountered, they reported the following:

- The GPS accuracy is poor, so that operations cannot be started at the correct location.
- Manual operation response is overall quite slow.

- It is difficult to operate this controller while driving the vehicle because of its touch panel.

Delay in operations and response in snow and ice work that should be done while moving is a serious problem. Such a device controller needs to be operated securely and swiftly even when there is heavy snow or under pressing conditions. We are currently implementing evaluations and improvements for these known problems. Field tests will be conducted in the first half of 2014, and the actual use is expected to start from 2015.

In the future, we aim to coordinate this controller with the GPS vehicle location management system so as to achieve more detail in operating control. In addition, we are considering the sharing of operating information with other equipment such as information boards and administrative offices in order to develop a service to provide customers information about the current location of each snow-plow truck and estimated time for elimination of mobility limitation associated with echelon snow removal work.

３-２ GPS Vehicle Location Management System

The GPS vehicle location management system utilizes digital wireless technology and the vehicle monitoring system based on GPS signals. This system is currently introduced to a part of the NEXCO Group, helping in giving swift and proper instructions to the vehicles of the traffic control team and to operate snow and ice removal vehicles effectively. Figure 5 shows the configuration of the system introduced in the Niigata Operation Base. Each administration office has the network control system for digital wireless equipment which is connected to the vehicle location management system. Through this system, the vehicle location information of each office is integrated with the Branch Operation Base via LAN.

This was conventionally done by telling the vehicle location information and operation contents by wireless radio to the snow and ice task force. The whole operation was previously managed by doing this. In the case where multiple vehicles were used for operations however, interference or cross talk often occurred, causing difficulty in hearing what was being said. The GPS vehicle location management system uses digital radio communication and transmits location information and operation information from the on-board device installed in the operation vehicle to the snow and ice management office. With these features, operation conditions can be managed in an integrated manner. This also serves to reduce burden in communications on radio between operators, decreasing the interference probability.

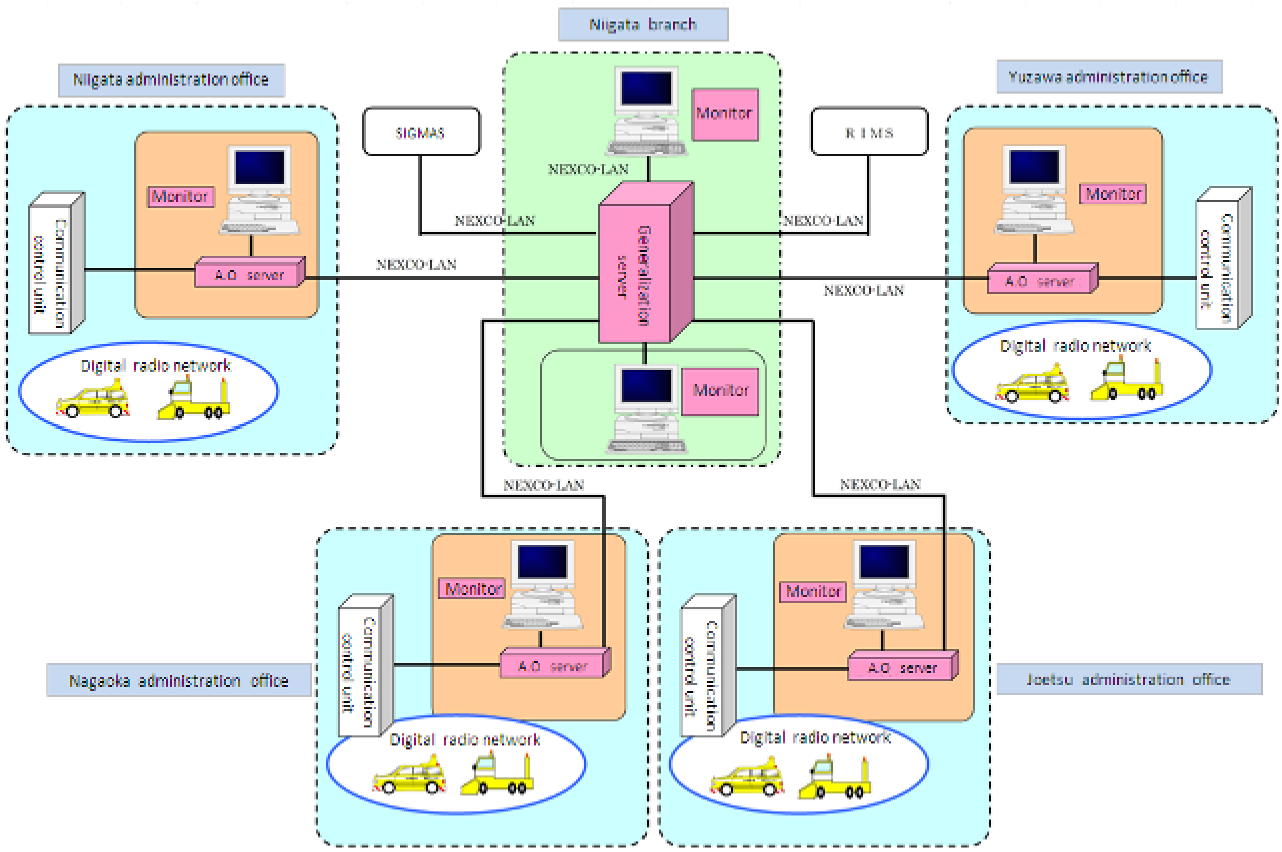

Figure 5 - System configuration (Niigata Operation Base)

The functions of the GPS vehicle location management system are as follows:

- Indication of vehicle locations and operational contents

This function has made it easier to understand the operational conditions on site by monitoring vehicle locations and operational contents displayed on the vehicle location monitor screen installed at the snow and ice task force (Figure 6).

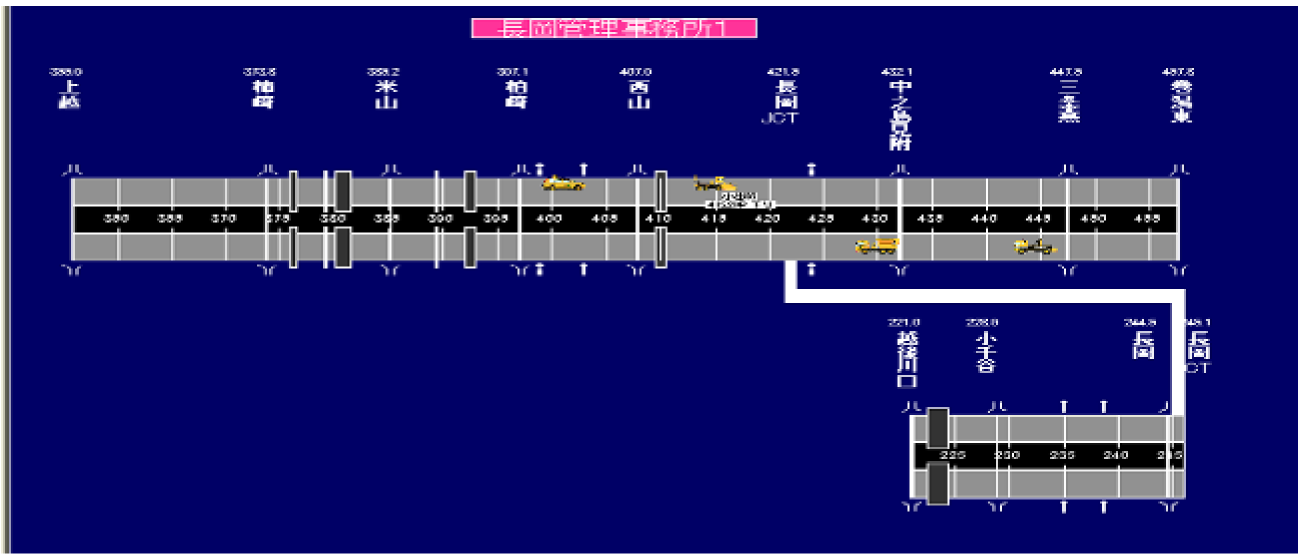

Figure 6 - Vehicle location monitor

- Kilometer Post Indication on the On-board Device

The on-board device of the GPS vehicle location management system (Figure 7) can indicate kilometer posts of highways. This device can also indicate pre-registered bridges and tunnels. Work with snow and ice vehicles is done while kilometer posts on the highway are confirmed. However, when snow has accumulated, these kilometer posts signs on the main road cannot be confirmed because of snow covering them. In addition, snow attached to the vehicle windows could block the sight of operators. Even in such a climate condition however, this function has enabled operators to get accurate information regarding their current position by showing kilometer posts on the on-board device.

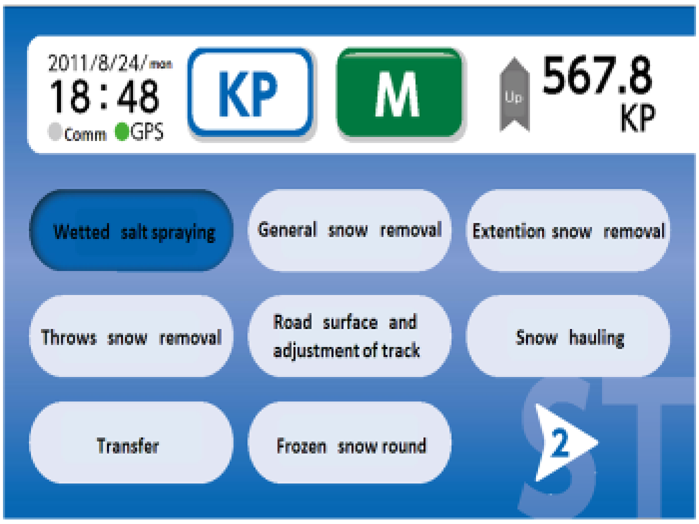

Figure 7 - On-board device screen

- Automatic Coordination with Road Information Boards

The automatic coordination with road information boards can be included as an example of the application of the vehicle location management system. With this function, vehicle location information and operational content information, which is transmitted to the integrated server of the GPS vehicle location management system from each on-board device, is sent to the traffic system that controls traffic information. By doing so, this function makes it possible to indicate information about snow and ice work currently being carried out automatically on each road information board.

This GPS vehicle location management system is actually introduced in municipalities other than Niigata. We have received favorable reports regarding this system, such as the decrease in radio communications and that work efficiency was improved. However, the positions of kilometer posts displayed on the on-board device sometimes had gaps. We need to improve this system furthermore by enhancing device accuracy.

3-3 Introduction of New Control Method based on Road Heating (RH) Operation

Due to the recent global warming trends, it has become possible to reduce the amount of power consumption of RH facilities during the winter season. The RH facilities have been operating at its original heat quantity rate despite the amount of snowfall. In order to further reduce the amount of electricity used during the winter season, we conducted an evaluation test for the new control method for road heating, where the traditional intermittent operation method (ON for 25 min. and OFF for 5 min.) was changed to the current-control method which is able to fallow the weather conditions, by introducing the new HR operation for selected tunnels under the jurisdiction of Niigata Operation Base.

The evaluation test for the new control method was conducted at the entrance of the Yakushi Tunnel on the outbound line in 2011. Upon conducting this evaluation test, the appropriate RH calorie for the Yakushi Tunnel was calculated based on climate data of 2001 to 2010. The designed HR calorie for the Yakushi Tunnel was 200W/m^2 at first, but it was reviewed and revised to 114W/m^2. This calculation confirmed that the required calorie was reduced by 57% of the initial designed calorie. The evaluation test results are described below:

- Road temperature condition out of the tunnel

As shown in Figure 8, the RH operation at the appropriate value of 114W/m^2 after review confirmed that the road temperature did not drop below zero degrees, even in a period of time when hourly snowfall amount reached 8.2cm. Snow melting performance was maintained well.

Figure 8 - Road condition of the Yakushi Tunnel

- Road temperature condition in the tunnel

The calorie of 160W/m^2 which is equal to that of the intermittent operation method did not also cause traffic trouble; however, it was not enough to ensure the road temperature of zero degrees or higher, showing deficient snow melting performance.

Based on the evaluation test results, in the tunnel, we have no other choice but to adopt the initial designed value (200W/m^2). In the portion out of the tunnel, however, this evaluation test confirmed that RH can be operated at the appropriate calorie after review (114W/m^2). Therefore, we started considering the introduction of the current-control operation method in other tunnels existing in the areas under the management of the Niigata Operation Base.

Table 1 indicates the calculation results of the required calories of various locations in the areas under the management of the Niigata Operation Base. Those tunnels in blue in Table 1 are the tunnels where the new RH operation method was selected and introduced in accordance with the flow shown by Figure 9. Table 2 indicates the power-saving results in 2012. Although the Yoneyama Tunnel without data obtained, when compared to the traditional intermittent operation method, we found that this new operation method could achieve a reduction effect and saved about 467,000 kWh of electricity which accounts to about 7,460,000 yen.

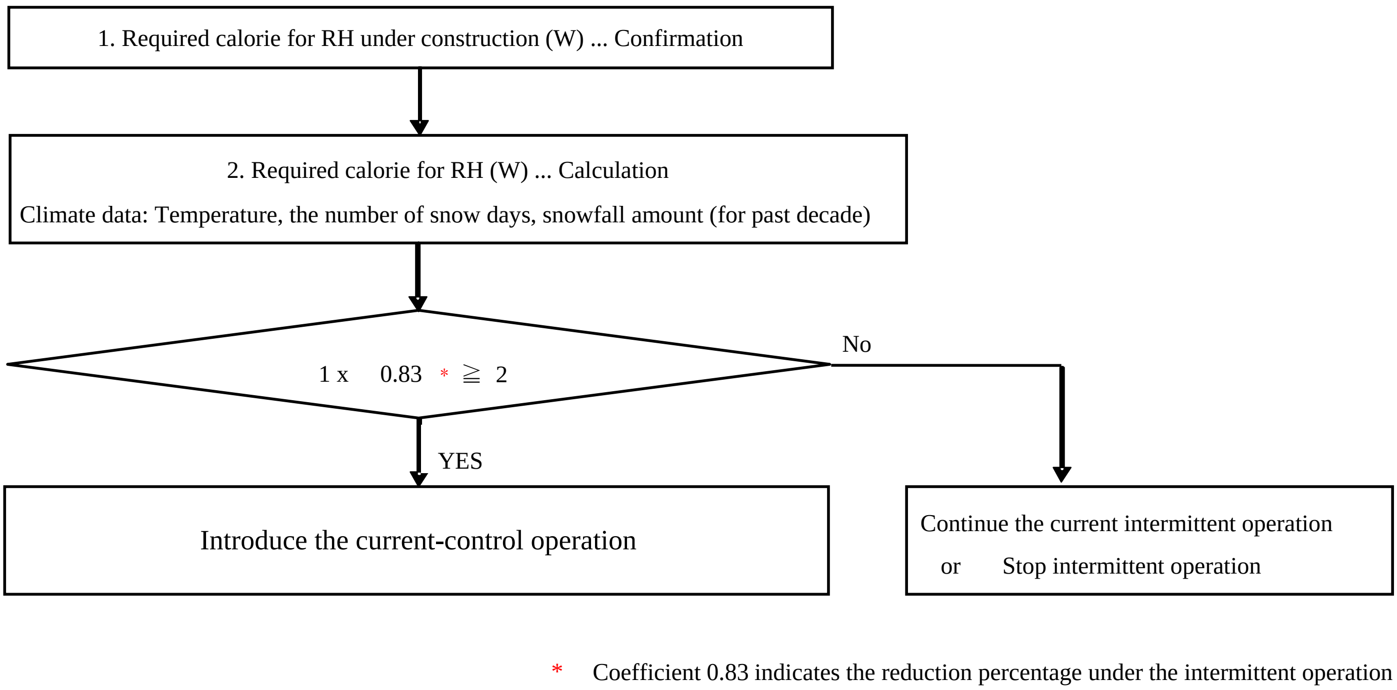

Figure 9 - A flow chart of the introduction of the current-control operation

Table 1 - Calculation results of required calories

Tunnel name	Up and down etc.	Inlet side and Outlet side etc.	Required calorific value (Reasonable value) (W/㎡)	Required calorific value (Original design value) (W/㎡)	Remarks
Kawakami	Up lane	Inlet side	108	200	Introduced(2012 year)
Kawakami	Down lane	Inlet side	108	200	Introduced(2012 year)
Muikamachi	Up lane	Inlet side	218	230	
Muikamachi	Down lane	Inlet side	218	230	
Echigokawaguchi	Up lane	Inlet side	252	230	
Echigokawaguchi	Down lane	Inlet side	252(349)	230(280)	
Yamamotoyama	Up lane	Inlet side	205	200	
Yamamotoyama	Down lane	Inlet side	252	230	
Yakiyama	Opposite lane	Niigata side	166(199)	220(267)	
Shozenji	Up lane	Inlet side	114	125	
Yakushi	Up lane	Outlet side	114	90	
Yakushi	Down lane	Inlet side	114	200	Introduced(2011 year)
Yakushi	Down lane	Outlet side	114	200	Introduced(2012 year)
Hanadate	Up lane	Inlet side	114	90	
Hanadate	Up lane	Outlet side	114	90	
Hanadate	Down lane	Outlet side	114	200	Introduced(2012 year)
Nadachi	Up lane	Inlet side	114		Introduced(2011 year)
Nadachiomachi	Up lane	Inlet side	114	95	
Nadachiomachi	Up lane	Outlet side	114	95	
Nadachiomachi	Down lane	Inlet side	114		Introduced(2011 year)
Nadachiomachi	Down lane	Outlet side	114	200	Introduced(2012 year)
Tokuai	Up lane	Inlet side	114	95	
Tokuai	Up lane	Outlet side	114(137)	95(125)	
Tokuai	Down lane	Inlet side	114		Introduced(2011 year)
Tokuai	Down lane	Outlet side	114	200	Introduced(2012 year)
Tsutsuishi	Up lane	Inlet side	114	95	
Tsutsuishi	Up lane	Outlet side	93(129)	95(125)	
Tsutsuishi	Down lane	Inlet side	93(129)	200(240)	Introduced(2012 year)
Tsutsuishi	Down lane	Outlet side	114(137)	200(240)	Introduced(2012 year)
Sanno	Up lane	Inlet side	93(129)	95(125)	
Sanno	Down lane	Outlet side	93(129)	200(240)	Introduced(2012 year)
Kazanami	Down lane	Inlet side	114(137)	200(240)	Introduced(2012 year)
Oyashirazu	Down lane	Outlet side	114(137)	200(240)	Introduced(2012 year)
Tenjindo	Opposite lane	Nagano side	196	261	
Tenjindo	Opposite lane	Jyoetsu side	196(271)	245(370)	
Kannondaira	Opposite lane	Nagano side	196(271)	245(370)	

※The numerical value in () shows a bridge part

Table 2 - Power-saving results in 2012

Receiving plant name	Operation pattern	Ratio of 100% operation	Total (Nov,2012～Apr.2013) Usage fee (Kwh)	Total (Nov,2012～Apr.2013) Amount (￥)	Power−saving result (Intermittent operation−Triac control) Usage fee (Kwh)	Power−saving result (Intermittent operation−Triac control) Amount (￥)
Kawakami tunnel (Snow melting)	Intermittent operation system	83%	66,882	1,245,044	23,368	435,007
	Current control system	54%	43,514	810,037		
Yoneyama tunnel (Snow melting)	Intermittent operation system	83%	—	—	—	—
	Current control system	41.5%	—	—		
Kakizaki tunnel (Snow melting)	Intermittent operation system	83%	18,411	773,105	8,096	339,980
	Current control system	46.5%	10,315	433,125		
Yakushi tunnel (Snow melting)	Intermittent operation system	83%	265,528	4,544,200	83,908	1,435,966
	Current control system	57%	181,620	3,108,234		
Nadachi tunnel	Intermittent operation system	83%	65,130	1,054,266	20,582	333,148
	Current control system	57%	44,548	721,118		
Tokuai tunnel	Intermittent operation system	83%	695,742	10,258,847	219,854	3,241,796
	Current control system	57%	475,888	7,017,051		
Sanno tunnel	Intermittent operation system	83%	97,814	1,578,378	43,234	697,643
	Current control system	57or46.5%	54,580	880,735		
Oyashirazu tunnel	Intermittent operation system	83%	213,882	3,091,274	67,587	976,842
	Current control system	57%	146,295	2,114,432		
T o t a l					466,629	7,460,382

＊For power distribution equipment modification work, measurement data missing.

4 Summary

Niigata is classified as part of the heavy snow area within Japan because of its climate characteristics. We endeavor to ensure a safer traffic environment in the winter season through technological development of the integrated device controller, the GPS vehicle location management system, and RH control technology. We actually face many issues with this development; however, we are about to solve these issues by conducting thorough review and trial evaluations.

With respect to the GPS location management system, this system has already been operated in the areas under the management of the Niigata Operation Base. We aim to establish the completed actual utilization of this system and the control method by adding additional functions.

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