EVALUATION OF THE TEN YEARS SINCE STUDDED TIRES WERE BANNED IN HOKKAIDO AND FUTURE ISSUES

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1. Introduction

In June 1990, the Japanese government enacted a law to regulate the use of studded tires.

Adoption of the regulations against the use of studded tires in cold and snowy Hokkaido presented a formidable challenge, with the apprehension that it might result in changes of the coefficient of friction between wheels and road surface, the physical index most closely related to kinetic functions of vehicles. In other words, it was a sort of large-scale social experiment. The decade of the 1990s was a transition period for Hokkaido, from a studded tire-dependent road traffic system to a studless tire- oriented one.

The positive effects of the studded tire regulations, observed for the past ten years, include the resolution of the problem of dust pollution caused by vehicles and a reduction in abrasion of pavement. Adverse influences have also been observed, such as the occurrence of "very slippery road surfaces", an increase in winter traffic accidents, the deterioration in winter traffic conditions and increase of travel cost, those impose large burdens on road users. In addition, the amount of anti-freezing agents and abrasives utilized by road administrators has rapidly increased.

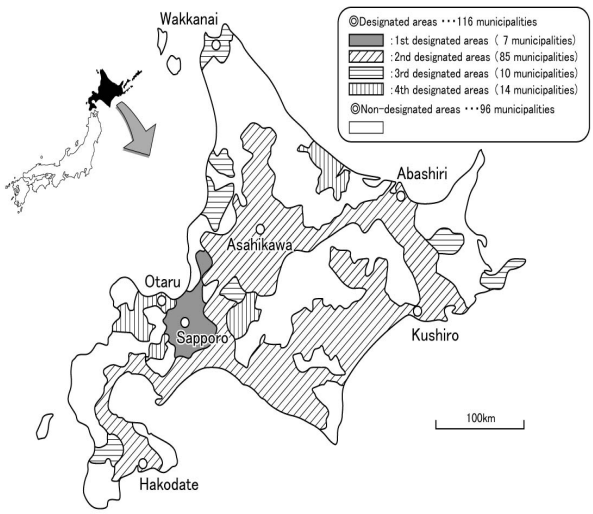

Figure 1 Areas Where Studded Tires Are Not Allowed

This paper examines the ten years of impact of studded tire regulation on the

environment, road surface management, winter traffic accidents, winter traffic conditions and opinions of residents. The study also conducted a cost-benefit analysis and identified future issues in relation to the performance characteristics of studless tires. These results are also reported.

2. Background and Effects of Studded Tire Regulation

2.1 Objectives and background

During the 1980s, studded tires became a social issue in Hokkaido as they began to cause several problems including vehicle-induced dust pollution, abrasion of pavement, and traffic accidents attributed to rutting on the pavement. Dust pollution, in particular, generated by vehicles through abrasion of pavement, was considered a serious problem by citizens.

Various citizens' activities and discussions led to voluntary controls on the manufacture and sale of studded tires, as well as the enactment of ordinances by the Hokkaido prefectural government and the Sapporo municipal government. Eventually, in June 1990, the national government enacted the Law to Prevent the Generation of Particulates from Studded Tires, which includes an article stipulating that no person shall use studded tires on any snowless or unfrozen road sections where cement concrete pavement or asphalt concrete pavement is applied to the road surface in the designated area. Since April 1992, a fine has been imposed.

2.2 Expansion of designated areas and changes in equipping rate

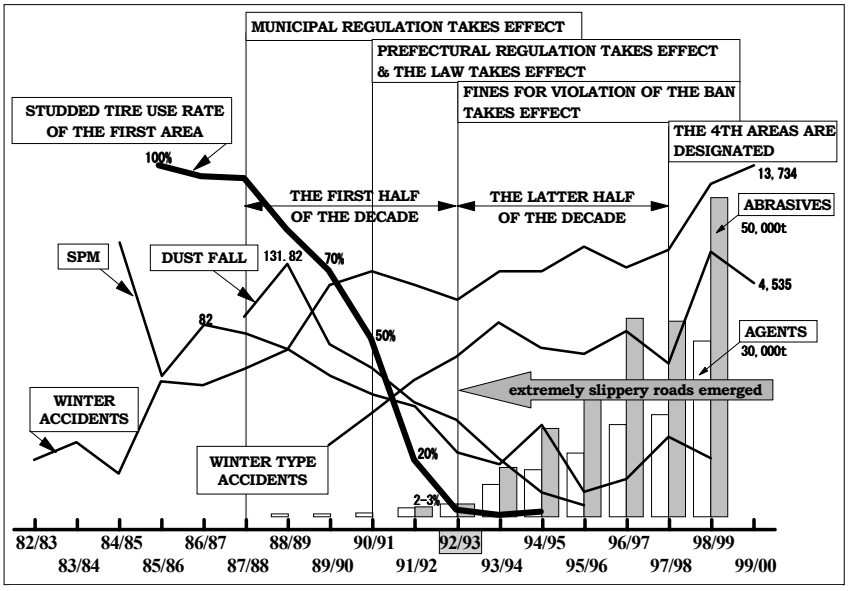

Figure 2 Changes in the Equipping Rate of Studded Tires and Other Indices

In accordance with the law, the areas in Hokkaido where studded tires were not allowed were designated in four phases as shown in Figure 1. The equipping rate of studded tires in the first designated area dropped to nearly 0% in 1992 (Figure 2), and those for the second and third designated areas approached 0% in 1993 and 1996 respectively. Currently, 116 of the 212 municipalities in Hokkaido fall into a designated area, and 89% of vehicle owners are subject to the regulation against the use of studded tires. Looking back, it seems that studded tires became obsolete in Hokkaido virtually upon the law's enactment, and the tire industry stopped the production of studded tires.

2.3 Effects on the environment

The secular variations in the annual maximum of the daily mean for the concentration of suspended particulate matter (SPM), measured along a given roadside within Sapporo, indicate

that the 1985 value met the requirement of the environmental quality standard (100 μg/m^3). This accomplishment is regarded as a result of intensive guidance provided by the City of Sapporo, which urged the citizens to voluntarily refrain from using studded tires. From that point, the SPM value gradually decreased (Figure 2), and has remained around the 40 μg/m^3 level since 1992.

According to the survey results for the quantity of dust fall (smoke and dust, among various materials in the air, fallen by gravity and rain) recorded at the same location, the annual maximum monthly dust fall decreased to about one tenth, from approximately 130t/ km^2/month in 1988 to approximately 12t/km^2/month in 1995 (Figure 2), assuring a positive effect on the environment.

At this point, no environmental quality standard has been established for the amount of dust fall.

2.4 Effects on road surfaces

Since the equipping rate of studded tires has approached 0%, the former problem of pavement abrasion has been resolved.

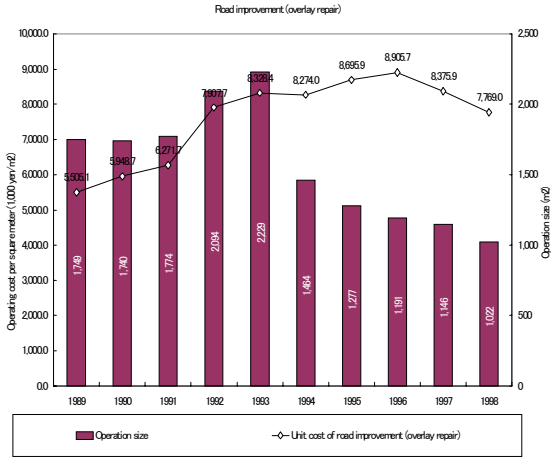

Figure 3 Changes in quantity of pavement overlay applied to national highways.

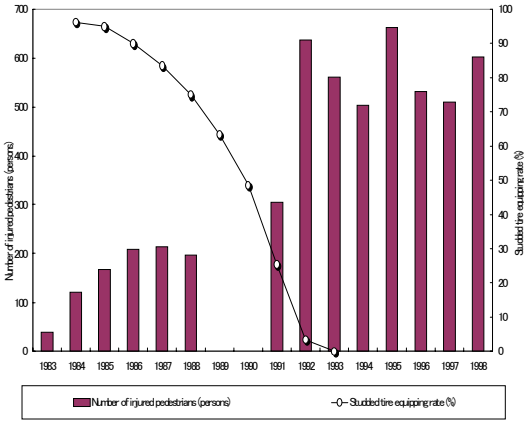

Figure 4 The number of pedestrians who were injured by falls on winter roads and required ambulance care, and the equipping rate of studded tires in Sapporo

A questionnaire was addressed to the Hokkaido Development Bureau, to identify types of operations that were affected by the studded tire regulations among all winter road management operations carried out by the road administrators. The results showed that a change was observed in the quantity of pavement overlay applied to national highways. The quantity of pavement overlay had been increasing until 1993, and then began to decrease. The value for 1998 decreased to nearly half that of 1993.

3. Effects on Road Surface Management, Traffic Accidents, and Traffic Conditions

3.1 Changes in application amount of anti-freezing agents

In the winter of 1992 when the equipping rate of studded tires approached 0% in Sapporo, "very slippery road surfaces" occurred which had not been seen previously. This was because the studless tires buffed the snowy and icy road surface. In the winter of 1991, when the equipping rate was nearly 20%, the "very slippery road surfaces" did not occur, and the environmental quality

standard for SPM was achieved.

In those years when both studded tires and studless tires were used concurrently, pins on studded tires are thought to have roughened the snowy and icy road surfaces, preventing the occurrence of the "very slippery road surface" phenomenon.

The Hokkaido Development Bureau, which manages all national highways in Hokkaido, had rarely used anti-freezing agents and anti-skid materials until 1992. However, to respond to the occurrence of "very slippery road surfaces" in the winter of 1992, the Bureau began to use those chemicals substantially from the winter of 1993, so that the amount of chemicals applied increased rapidly (Figure 2), causing expenditures to soar as well.

3.2 Changes in the number of winter traffic accidents

Changes in the number of traffic accidents in Hokkaido during a winter season from November to March were examined. Here, an accident is defined as that resulting in injury or death. The number increased along with the diffusion of studless tires, and the rate of increase between 1989 and 1999 was about 20%, rising from nearly 11,000 to 14,000 cases (Figure 2). No noticeable increase was found in the death toll, which remained at around 200 fatalities.

Among all winter traffic accidents, those caused by slipping, rutting, and reduced visibility were combined as winter-type accidents. The number increased until 1993 as the equipping rate of studless tires rose, and another tendency to increase has been seen recently. Slipping accidents account for most of the winter-type accidents.

It must be mentioned that the number of pedestrians who slipped and fell on winter roads increased after the enactment of the regulations studded tire. Figure 4 shows the relationship between the number of pedestrians who were injured by falling on winter roads and required ambulance care, and the equipping rate of studded tires in Sapporo. A big difference is seen in the number of injured pedestrians, with the year 1992 as a turning point when the rate approached 0%, although the data for 1989 and 1990 are missing for some reason. It has been ironically pointed out that the dust produced by studded tires made surfaces of pedestrian roads less slippery.

3.3 Changes in over-all traveling speed

Unfortunately, few investigations have been made of the traffic volume and the overall traveling speed in winter. A road traffic census for the winter period (winter traffic survey) was

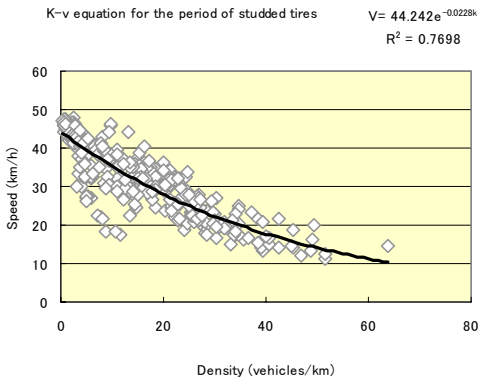

Figure 5 K-v Equation for Period Before Enactment of Regulations of Studded Tire

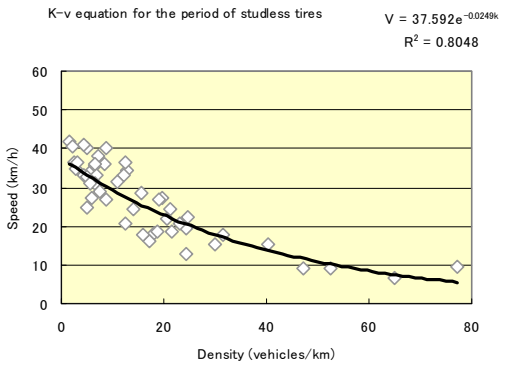

Figure 6 K-v Equation for Period After Enactment of Regulations of Studded Tire

partially conducted in 1997. Therefore, by using the survey results introduced in Figure 1, we compared the overall traveling speeds on days of snowfall, before and after the enactment of the regulations of studded tire. Based on these survey results, the k-v equation, which expresses the relationship between traffic density and speed, was formulated respectively for the periods before and after the regulation enactment (Figure 5 and Figure 6), to determine the overall traveling speed for each major trunk road in the Sapporo region. As a result, it was found that the overall travelling speed for each road decreased by 5km/h to 6km/h.

Table 1 Winter Traffic Surveys Referred to in Comparing Overall Traveling Speeds

Time period	Year	Title of survey	Roads surveyed	Survey method
Period of studded tires	February 1986	Study on the reliability assessment of road traffic(Hokkaido Development Bureau)	Six national highways in Sapporo and its environs	Twelve-hours four-day winter survey on traveling speed and traffic volume
Period of studless tires	December 1997 to February 1998	Winter traffic survey	Major trunk roads in the city of Sapporo and Ishikari Subprefecture	Twelve-hours traffic volume survey and peak-hour traveling speed survey on days when snowy and icy road surfaces occurred between December and February

Table 2 Distribution and Collection of Questionnaire

Ward and city	Street	Number of household (as of October 1, 2000)	Number of questionnaires distributed	Number of questionnaires collected (Sampling number)	Sampling rate
Toyohira, Sapporo (on National Highway Route 36)	Tsukisamu Chuo-dori 3 to 10	1,231	418	62	5.0%
Hiragishi, Sapporo (on Kanjo-dori)	Kita 15, Higashi 10 to 15 Kita 16, Higashi 10 to 15	1,299	368	74	5.7%
Shiroishi, Sapporo (on Atsubetsu-dori)	Kawashimo 4, 2 to 5 Kawashimo 5, 1 to 4	779	371	118	15.1%
Unidentified	-	-	-	18	-
Total		3,309	1,157	444	13.4%

4. Survey on Citizens' Awareness

A questionnaire survey was carried out in April 2001 to determine any environmental changes after the introduction of studless tires. Table 2 shows the areas covered, in which a similar survey was conducted in 1988.

The respondents consisted of 80% males and 20% females. Nearly 90% of all respondents were 40 years old or over.

About 80% of the respondents felt that polluted winter air was "improved", and were generally satisfied with current air conditions (Figure 7). Regarding traffic congestion and the risk of accidents while driving on major trunk roads in winter, about 60% of the respondents felt the situation had "worsened", and 30% answered "unchanged" (Figures 8 and 9).

Concerning the general evaluation, slightly less than half the respondents marked "improved". When "unchanged" and "worsened" are combined, their percentage came close to that for "improved" (Figure 10).

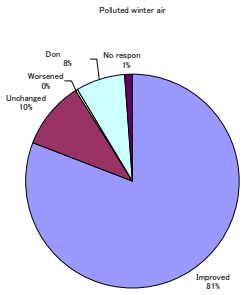

Figure 7 Questionnaire Results (Polluted Winter Air)

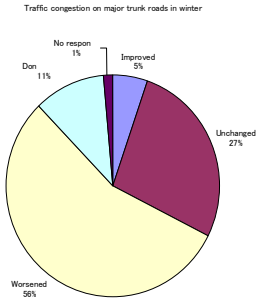

Figure 8 Questionnaire Results (Traffic Congestion on Major Trunk Roads in Winter)

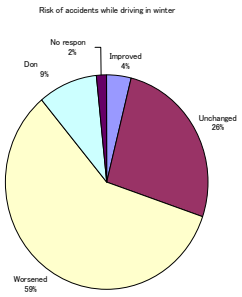

Figure 9 Questionnaire Results (Risk of Accidents While Driving in Winter)

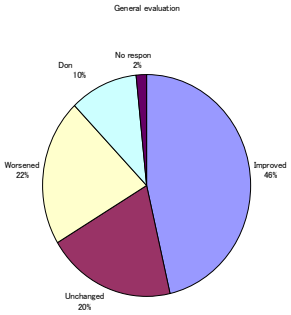

Figure 10 Questionnaire Results (General Evaluation)

5. Cost-benefit Analysis of Regulation of Studded Tires

A cost-benefit analysis was carried out on the regulation of studded tires. Items affected by the shift from studded tires to studless tires have been converted into monetary values wherever possible, to estimate costs and benefits, or losses. Ishikari Subprefecture, with the city of Sapporo as its center, was chosen as the area to be investigated, since the work of covering all of Hokkaido was too voluminous to achieve.

The estimated items and calculation methods are as follows.

5.1 Increase in loss of traveling time

By using the survey data introduced in "3.3 Changes in overall traveling speed", the value of vehicle-kilometer of travel calculated for each relevant major trunk road was divided by the value of its corresponding overall traveling speed and multiplied by the basic unit of time value for vehicle types to estimate the daily loss in running time. The result was then multiplied by the number of snowfall days when snowy and icy road surfaces were perceived to emerge, and the loss of traveling time for a given winter was determined.

5.2 Increase in traveling cost

Fuel costs per kilometer before and after the enactment of regulation on studded tires in Hokkaido were derived from the total vehicle-kilometer of travel and the total fuel consumption for freight vehicles and passenger cars in the Statistics of Automobile Transport published by the former Ministry of Transport. Then, the values were multiplied by the total vehicle-kilometer of travel for the investigated area to obtain the increase in traveling cost from the standpoint of fuel consumption.

In addition, a tire's unit price to a traveling distance was calculated on the basis of the average unit price of tires and their average durable traveling distance that had been estimated from the average durable time. The result was then multiplied by the vehicle-kilometer of travel. Finally, the increase in traveling cost was determined after calculating the difference between the cost of purchasing tires before and after the enactment of regulation on studded tire.

5.3 Increase in losses from traffic accidents

The average amounts of losses by types of accident were derived from source materials issued by the Marine and Fire Insurance Association of Japan, Inc. Then, the numbers of accidents by type before and after the enactment of studded tires regulation within the area were calculated from the accident rate per vehicle-kilometer of travel. These two values were multiplied by each other to determine the amount of losses attributed to the increase in traffic accidents.

5.4 Losses from air pollution

Due to the fall in traveling speed, an increase in NOx emissions is to be expected along the roadsides of major trunk roads. Economic losses associated with environmental deterioration accompanying the increase in NOx emissions attributed to the fall in traveling speed were calculated from the basic unit of environmental assessment.

5.5 Benefit of noise reduction

The benefit of reducing noise (equivalent noise level) from the period before to the period after the regulation enactment was calculated from the basic unit of noise improvement benefit.

5.6 Benefit of scenic improvement

The benefit brought by scenic improvement was estimated by using the contingent valuation method (CVM) to determine the price people are willing to pay for scenic preservation if the use of studded tires were re-allowed and dust were to harm the scenery.

5.7 Reduction in cost of road surface repair

The reduction in the cost of pavement overlay projects, one of the most significant effects brought about by the studded tires regulation, was examined as a benefit.

5.8 Increase in costs for measures against frozen road surfaces

The increase in costs for measures against frozen road surfaces, including application of anti-freezing agents to counter the occurrence of "very slippery road surfaces," was calculated as a loss.

The analysis results are shown in Table 3.

Table 3 Results of Cost-benefit Analysis of the Regulation on Studded Tire

	Road administration body		Road users	Residents	Total
	National	Local			
Increase in traveling time			- 11,133		- 11,133
Increase in travel cost (fuel, tires)			-5,660		-5,660
Increase in traffic accidents			- 687		- 687
Air pollution (NOx)				- 48	- 48
Noise reduction				446	466
Scenic improvement overlay				1,461	1,461
Cost of pavement overlay	129	22			151
Cost for measures against frozen road surface	- 335	- 647			-982

Unit: million yen / year

As a consequence of the enactment of the regulation on studded tires, the noise reduction, scenic improvement, and cost reduction in pavement overlay were identified as beneficial effects, while adverse effects include loss from increases in traveling time, traveling cost, losses from traffic accidents, and cost for measures against frozen road surfaces.

Concerning the influence of dust on human health, which was the prime motive behind the regulation, it was not possible to conduct a cost-benefit analysis on this subject because no monetary evaluation methods were available. For this reason, measurement of effects may not be sufficiently thorough, but the most affected items were loss from increase in traveling time and traveling cost. The regulation of studded tires substantially benefited the environment in exchange for the large burdens on not only road administrations but also on road users in the aspects of loss from increase in traveling time, traveling cost and traffic accidents.

6. Influence of Studded Tires on Snowy and Icy Road Surfaces

As already mentioned in "3.1 Changes in application amount of anti-freezing agents", the requirements of the environmental quality standard were met without the occurrence of "very slippery road surfaces" in the winter of 1991 when the equipping rate of studded tires was about 20%. In February 2001, our research group carried out a comparative test to clarify the influence of braking function (ABS position) of vehicles on a snowy and icy road surface at studded tire equipping rates of 0% and 20%. One out of five test vehicles was equipped with studded tires to make a 20% equipping rate. The test was carried out after sunset to avoid the influence of sunlight, and the temperature was -10℃ to -15℃.

The "very slippery road surface" had already occurred by the time the fiftieth vehicle passed (Figure 11). Coefficients of friction were 0.42 for a 20% studded tire equipping rate and 0.21 for a 0% rate, indicating that studded tires certainly roughened the snowy and icy road surface. Further tests for other than the braking period are planned for the future.

The effectiveness of studless tires on snowy and icy road surfaces is undoubted; the problem is that driving only with studless tires facilitates the formation of slippery road surfaces.

(Without studded tires) (With 20% studded tires)

Figure 11 Differences in Road Surface Condition With/without Studded Tires

7. Summary and Future Issues

The findings are summarized as follows.

1. Studded tires are virtually not in use today.
2. Environmental problems (vehicle-induced dust pollution) such as suspended particulate matter and dust fall were remedied.
3. Abrasion of pavement caused by studded tires was ameliorated and the repair cost for pavement overlay was lowered.
4. Studless tires facilitate the formation of slippery road surfaces, and "very slippery road surfaces" occurred when the studded tires equipping rate approached 0%.
5. Slipping accidents increased during winter.
6. Winter traffic conditions deteriorated.
7. The survey on traffic awareness revealed that most citizens recognized positive effects on the environment, but pointed out that they faced aggravated situations in terms of traffic congestion and safety issues in winter.
8. The results of cost-benefit analysis indicated that the regulation of studded tires impose burdens on not only road administrations but also road users in the aspects of losses from increase in traveling time, traveling cost and traffic accidents.
9. However, according to the general evaluation in the awareness survey, nearly half the respondents answered that the situations were "improved from before", while "unchanged" and "worsened" combined to account for nearly half the total. Based on these results, it was difficult to conduct an accurate evaluation of the effects of studded tires regulation.

In the light of its highly evaluated effects on the environment, studded tire regulation might be considered generally successful, and it is unlikely that studded tires will come back into common use.

Rather, it remains for certain issues to be addressed.

The primary solution to these problems would be to develop a tire that works effectively on frozen road surfaces without damaging the pavement. At this stage, however, it is impossible to produce such a tire.

On the other hand, lightweight studded tires were recently developed in Nordic countries with the aim of reducing pavement abrasion. They do not affect pavement abrasion in the same way as heavy as former studded tires. Effective use of such lightweight studded tires may reduce occurrence of extremely slippery winter road conditions and thus their introduction would attract our considerable attention.

Other some provisional solutions are suggested below.

* Approaches from the standpoint of technological development

1. Effective and efficient distribution of existing anti-freezing agents and anti-skid materials
2. Development of cost-effective and environmentally friendly anti-freezing agents and anti-skid materials.
3. Improvements in pavement structure, including freezing-prevention pavement and a low-cost road heating system.

* Approaches taking into consideration the effects of studless tires on snowy and icy road surfaces

4. Use of studded tires or chains (including non-metal chains) during the period when most roads within the city are covered with snow and ice (January and February in the case of Sapporo).
5. Allowing studded tires and chains (including non-metal chains) for light motor vehicles, which do less damage to pavement, and public transportation such as buses on regular routes.

* Other

6. Promotion of intra-city comprehensive traffic measures including the Traffic Demand Management (TDM).

There is no miracle solution to the problems.

However, it is necessary for both the Administration and citizens to be well aware of the problems in common that road users are imposed large burdens; and winter road management measures as well as technological development, including intra-city comprehensive traffic measures for winter, must be squarely addressed.

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