Jun 19, 2008

OICA Study about Influence Factors to the Low Tire Pressure Warning Threshold

(1) Study results

1) There is an afraid where the following equivalent tire pressure change will occur in a short period after adjusting the tire pressure to the recommended pressure. Total Equivalent Pressure change will be caused by Ambient Temperature Change, Accuracy of Pressure Gauge in the market, Accuracy of Pressure Sensor of TPMS, Pressure adjustment at Hot Condition in the market and Natural Tire Pressure Loss. See Table 1 and 2 below.

Total Equivalent pressure change :

1 day : 35 ~ 55 kPa
1 week : 43 ~ 63 kPa
1 month : 55 ~ 75 kPa

Assumptions used :
Recommended tire pressure P_{rec} : 200 kPa
Low pressure warning threshold : Prec – 25% (= 150 kPa for the tire described above.)

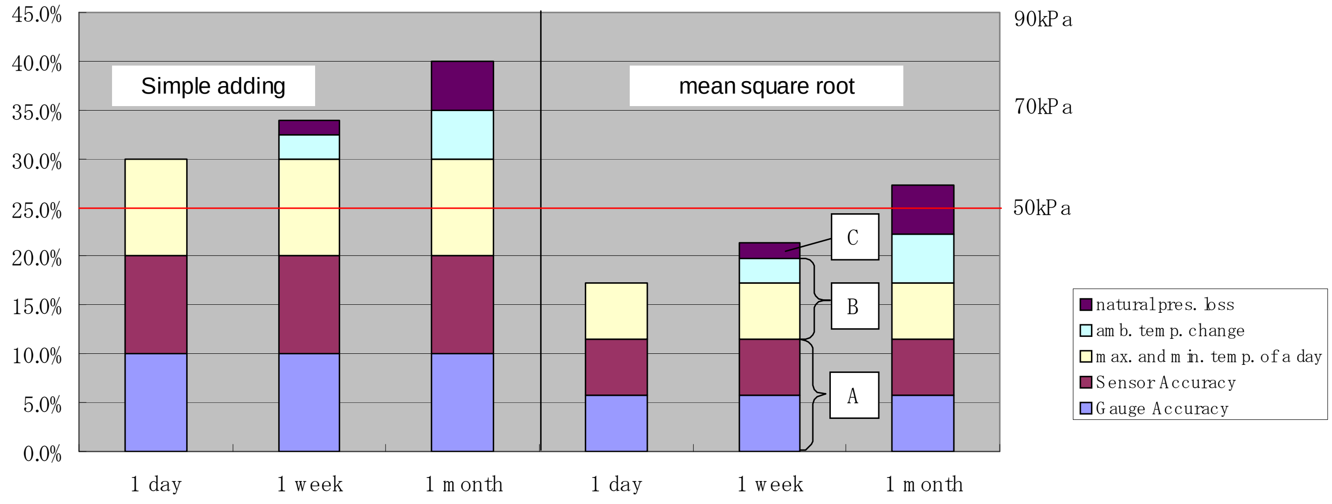
Table 1　Summary of Pressure Change Factors

	Cause		Remarks
1	Temperature change	a. Daily change :5 kPa ～ 20 kPa	Difference between Max. temperature of certain daytime and Min. temperature of the next day early in the morning. "20kPa" is used in the calcuration below.
		b. Weekly change :about 5 kPa	Approximate Difference between Average temperature of certain week and the next week. In this calculation, the season from late autumn to winter is considered.
		c. Monthly change :about 10 kPa	Approximate Difference between average temperature of a day and that of a month later. In this calculation, the season from late autumn to winter is considered.
2	Pressure gauge accuracy	±20kPa	e.g. :Although the gauge indicates 200kPa, the tire is inflated to only 180 kPa.
3	TPMS sensor accuracy	±10kPa	e.g. : If TPMS shall be guaranteed to warn low pressure at 150kPa, designed warning threshold must be set to 160kPa. In this case, there is the possibility that TPMS warnes low pressure at 170 kPa.
4	Adjust pressure in Hot condition	20kPa	Tire pressure rise caused by vehicle running from cold condition is about 20kPa. If the tire pressure is adjusted to 200kPa while the tire is in Hot condition, it is in reality, same as the tire is adjusted to 180kPa in Cold condition.
5	Natural tire pressure loss	6kPa ～ 18kPa / month	"10kPa" is used in the calculation below.

Table 2　Summary of Equivalent Pressure Change

	Adjust pressure in Cold		Adjust pressure in Hot	
	simple adding [kPa]	mean root square [kPa]	simple adding [kPa]	mean root square [kPa]
1 day	60	35	80	55
1 week	68	43	88	63
1 month	80	55	100	75

Graph 1　Equivalent Pressure change (Adjusted in Cold condition)

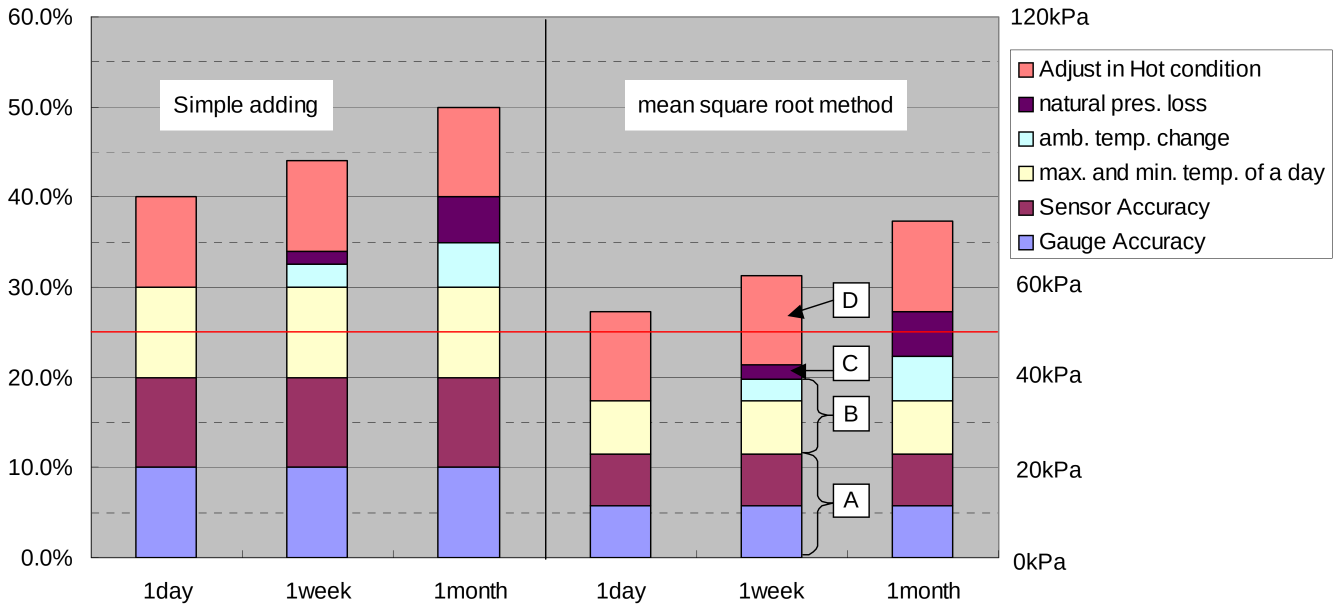


A : Equivalent pressure change caused by the accuracy of the sensor and the gauge

B : Equivalent pressure change caused by ambient temperature change

C : Natural tire pressure loss

Graph 2 Equivalent Pressure change (Adjusted in Hot condition)



D : The tire pressure is in reality, lower by 20 kPa or more from recommended tire pressure when it is adjusted in Hot condition.

1)-1 Tire Pressure Change by Ambient Temperature Change :

Japan extends long in a north-south direction. It is useful to study the latitudinal climate difference.

Daily Change:	5 ～ 20	kPa	(Northern part of Japan)
	5 ～ 15	kPa	(Central part of Japan)
	3 ～ 13	kPa	(Southern part of Japan)

Daily change of temperature is the largest in northern part of Japan.

Weekly Change : approx. 5 kPa

Weekly change of temperature has same tendency from northern part to southern part of Japan.

Monthly Change : approx. 10 kPa

Monthly change of temperature has same tendency from northern part to southern part of Japan.

Daily change of temperature : The difference between the highest temperature of one day and the lowest temperature of the next day. The purpose to calculate this value is to know, in case when tire pressure is adjusted in daytime, how much pressure will decrease in the morning next day. Generally, tire pressure becomes 10kPa lower by 10℃ decrease.

For detail of climate data, see Graph 3 ~ Graph 6.

1)-2 Equivalent Tire Pressure change by Tolerance of Pressure Gauge used in the market :

10～20kPa

Present Capability of Air gauge in the market

±10～±20kPa
Reference JIS（JISD8201）: Tire Gauges for Automobiles
Accuracy ±10kPa ~ ±20kPa

The Accuracy of a gauge equipped with a pressure adjusting device commonly used at gas stations is ±20kPa.

1)-3 Equivalent Tire Pressure change by Tolerance of Pressure Sensor of present TPMS

It is necessary to design the higher value than the prescribed threshold value to guarantee the worst case.

20kPa

Present Tolerance of TPMS pressure sensor

±10kPa

For example, if the tolerance of the sensor is ±10kPa, and the described warning threshold is 150kPa, the designed value for warning threshold shall be 160kPa. Therefore, in some cases, the TPMS will warn low pressure even the tire pressure is 170kPa, because of the sensor tolerance.

1)-4 It is difficult to ignore the case where pressure adjustment is done at hot condition in the market. In this case, the equivalent pressure is lower than the intended adjustment pressure.

Pressure difference between Hot condition and Cold : 20kPa

1)-5 The Factors from 1)-1 to 1)-4 will make the Equivalent Increase of the prescribed threshold value as follows;

Simple adding:

20 + 20 + 20 = 60kPa (Pressure is adjusted under Cold condition.)

20 + 20 + 20 + 20 = 80kPa (Pressure is adjusted under Hot condition.)

Root mean square:

$\sqrt{(20^2+20^2+20^2)}$= 35kPa (Pressure is adjusted under Cold condition.)

$\sqrt{(20^2+20^2+20^2)}$+20 = 55kPa (Pressure is adjusted under Hot condition.)

We believe it is a rare case that 3 worst conditions happen at the same time. Therefore we use root mean square method for addition.

3 worst conditions

1. The accuracy of the TPMS pressure sensor is worst.
2. The accuracy of the pressure gauge used for adjustment is worst.
3. The tire pressure is adjusted at the highest temperature of daytime and the vehicle is run at the lowest temperature early in the morning.

Weekly or monthly change of the pressure caused by corresponding temperature change shall be simply added.

2) The General Natural Pressure Loss is as follows;

6 ~ 18 kPa / 1 month

Therefore even if the threshold value is –25% (the same as FMVSS138), there is a possibility that the low pressure warning will come out in a very short period after the tire pressure is adjusted to the recommended value by the user.

3) Actually in the US, there was much claim of early warning from the market after the entry into force of FMVSS138 and NHTSA made the campaign to try to solve this issue and it is necessary to still watch the situation carefully.

NHTSA TPMS Public Service Announcement outline

FMVSS138 phase-in

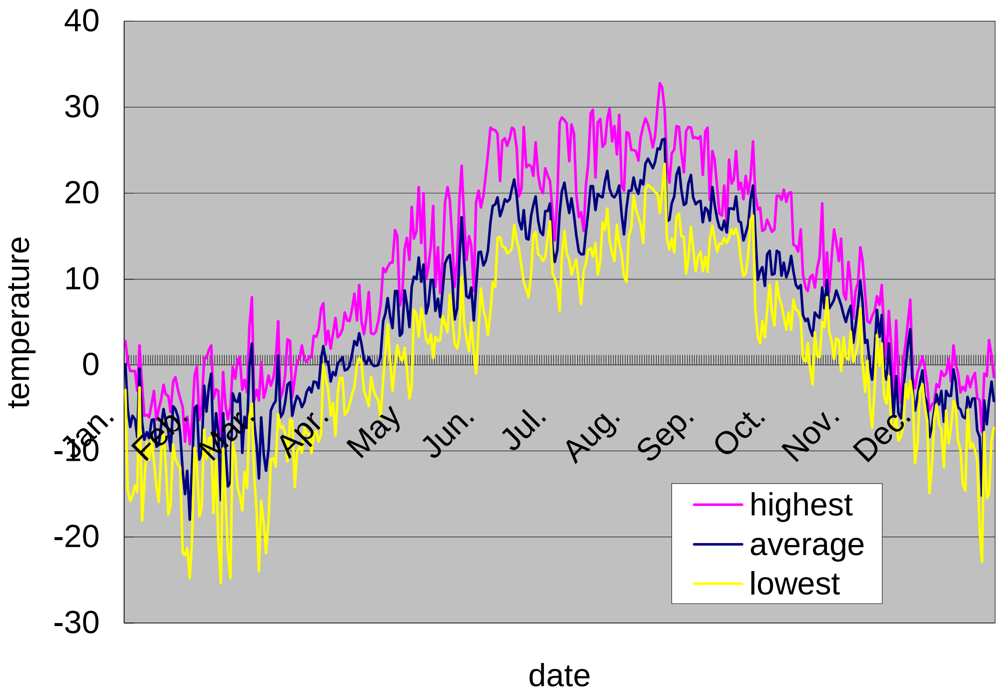
・70% vehicles manufactured on or after September 1,2006.

・100% vehicles manufactured on or after September 1,2007.

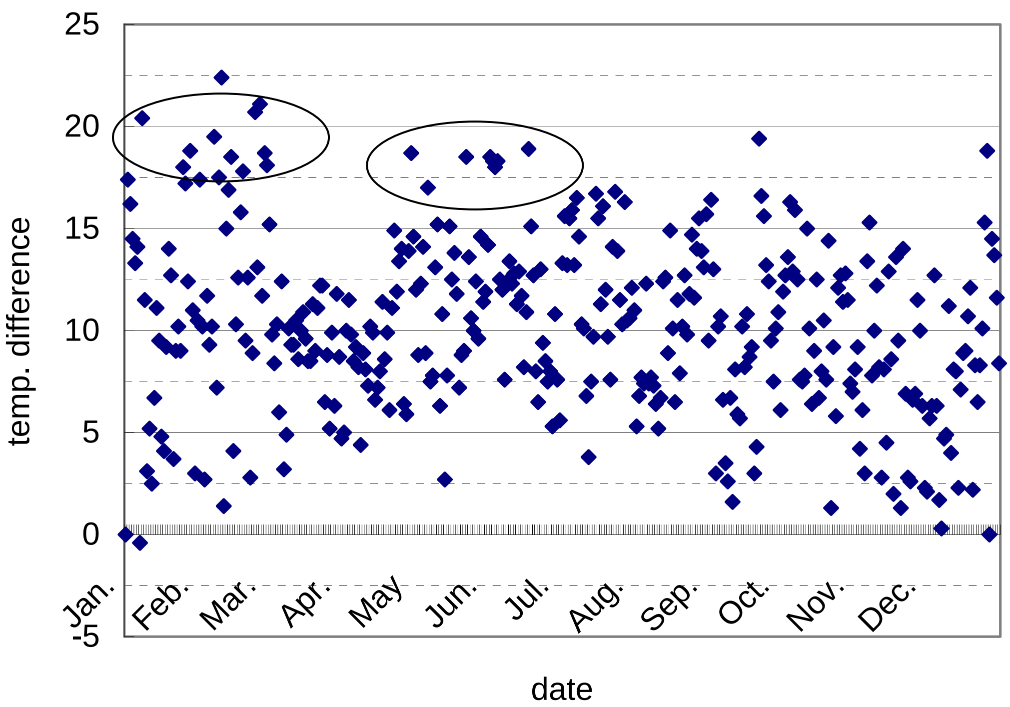
・There were a lot of claims from consumers about too early warning, Alliance of Automobile Manufactures requested TPMS Public Service Announcement to NHTSA.
It was launched in October, 2006.

4) It is very important to maintain the consumer acceptance in the market. Therefore the threshold value of 25% same as FMVSS138 will be appropriate considering the aforementioned reasons.

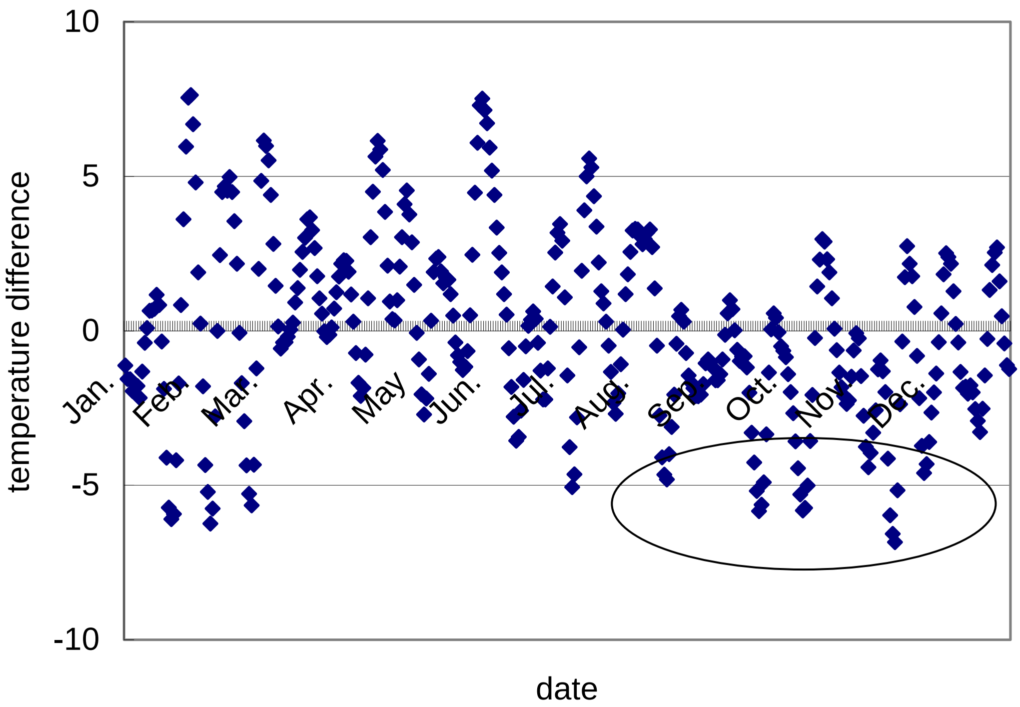
Graph 3　Daily Temperature (Shibetsu, Hokkaido, Japan)



Graph 4　Temperature difference between highest temperature of certain daytime and lowest temperature of early in the next morning



Graph 5　Temperature change of 1 week later



Graph 6　Temperature change of 1 month later.