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Ref. No.: GR04-046

Ms. Kathleen C. DeMeter, Director
Office of Defects Investigation NVS-214
National Highway Traffic Safety Administration
400 Seventh Street, SW
Washington, DC 20590

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OFFICE OF DEFECTS
INVESTIGATION

RE: NVS-214SS - EA03-024 Subaru WRX

Dear Ms. DeMeter;

This letter is in response to questions 1 through 5 of your letter dated July 16, 2004 concerning the Agency's Engineering Analysis request (EA03-024) for additional information regarding allegations of extended stopping distance in 2002 and 2003 Subaru Impreza WRX vehicles.
Appendices that we considered to contain "confidential" data have been sent to the Office of Chief Counsel and removed from this response.
As requested in your letter, our response is provided after repeating verbatim the applicable request which is in bold text.

1. **Subaru's response to Request No. 9d of the EA-IR references the variables K1, K2, K3, K4, and K5.**

   a. **State the values for K1, K2, K3, K4, and K5 at the end of each of the following events (if these values are different for any or each of the vehicle's wheels, state the values for each wheel):**
      i. **a vehicle at a "vehicle traveling (cruising) status" if initial speed 40 mph on a smooth dry asphalt surface:**
      ii. **immediately subsequent to i) above, the driver initiates braking at a deceleration of 0.1 g's and decelerates at 35 mph; and**
      iii. **immediately subsequent to ii) above, the left front wheel hit a single bump of minimally sufficient severity to result in the activation of the ABS.**
      State the values for K1, K, K, K4, and K5 for seven additional sets of similar sequences of events as that described by i)

through iii) above, with the deceleration indicated in b) incremented by 0.1 g's for each subsequent sequence of events up to a maximum of 0.8g's;

b. State the values of for K1, K2, K3, K4, and K5 at the end of the following events (if these values are different for any or each of the vehicle's wheels, state the values for each wheel):

i. a vehicle at a "vehicle traveling (cruising) status" of initial speed 40 mph on a smooth dry asphalt surface;

ii. immediately subsequent to i) above, the driver initiates braking at a deceleration of 0.1 g's and decelerates to 35 mph; and

iii. immediately subsequent to ii) above, the left front wheel crosses an abrupt drop-off of minimally sufficient severity to result in the activation of the ABS.

State the values for K1, K2, K3, K4, and K5 for seven additional sets of similar sequences of events as that described by i) through iii) above, with the deceleration indicated in b) incremented by 0.1 g's for each subsequent sequence of events up to a maximum of 0.8 g's;

c. Would any of the values of K1, K2, K3, K4, or K5 at the end of events a-iii or b-iii above change if both front wheels had encountered the bump or drop-off? If so, please describe how they would differ.

Response 1a

The values for K1, K2, K3, K4 and K5 are different between front and rear wheels but the values are identical between left and right wheels.
The values will change as shown in the table in Appendix 1 according to vehicle deceleration which is detected by the G sensor. "0.32G" indicated in the table is the threshold value to determine a very-low-co road surface. The values shown in column (a) indicate those for 0.1G, 0.2G and 0.3G, and the values shown in column (b) indicate those for 0.4G, 0.5G, 0.6G, 0.7G and 0.8G.

Response 1b

The values are the same as Response 1-a, since they will not change by differences between a bump and a drop-off.

Response 1c

The values will not change even if both front wheels had encountered the bump or drop-off.

2. **For the purposes of this Request, ABS sensitivity refers to the level of percent wheel slip, the level of wheel acceleration/deceleration, or the time interval over which a certain level of percent wheel slip or a certain level of wheel acceleration/deceleration occurs at one or more wheels at which the ABS will activate and begin to control the percent wheel slip at one or more of the wheels. Does ABS sensitivity vary with vehicle speed? If so, describe how such speed sensitivity is implemented in the control logic of the ABS.**

Response 2

The ABS sensitivity will vary according to vehicle speed conditions as described below.
The conditions described in items 1) and 3) are applicable to both automatic and manual transmission vehicles. The conditions indicated in item 2) are applicable only to automatic transmission vehicles.

1) When the reference speed is equal or greater than 60km/h and also the G sensor value is smaller than 0.32G, the value of K2 will become small and the ABS sensitivity will increase (become sensitive).

   Note: "K2" is the negative value and it will become small, i.e. the absolute value will become large.

2) When the reference speed is equal or greater than 64km/h and also the G sensor value is greater than 0.5G, the value of K5 will become large and the ABS sensitivity will decrease (become dull). When the reference speed is equal or greater than 128km/h, the ABS sensitivity will decrease further (become duller).

3) When the reference speed is equal or greater than 70km/h, the value of K4 will become small and the ABS sensitivity will increase (become sensitive).

3. **Subaru's response to Request No. 9d of the EA-IR includes a discussion on the ABS learning function. In response to Request No. 9d, Subaru states: "The system monitors acceleration and deceleration in each of four (4) wheels while ABS is not controlled, and in the case a condition of acceleration and declaration over designated values were detected over designated times, wheel slip ratio that triggers ABS control would be changed to higher values.". With respect to that response, we have the following questions:**

   a. **Are there any cautions on testing an ABS unit with a learning function? Do we need to cycle the ignition key between every ABS test run to clear the learned changes?**
   b. **If non-ABS stops are monitored and the slop ratios are raised, how long are they raised (e.g., for the rest of the ignition key cycle, for**

more than one brake application invoking ABS, for more than one "build to depart, dump to recover" cycle during an ABS stop?)

c. **Are all four wheels' slip ratios that "trigger ABS control" changed equally? If not, are the wheel slip ratios that "trigger ABS control" of the wheels of either of the front or rear axles changed equally as a pair?**

d. **State the conditions (i.e., vehicle speed, coefficient of friction, and time between cycles) that would set the lowest wheel slip ratios possible for testing.**

e. **State whether 20 ABS stops on wetted Jennite (full low-co) change the ABS performance for the next stop over a vertical perturbation.**

f. **Specify the values of wheel acceleration and deceleration that cause changes in slip ratio triggers.**

g. **How does a very-low-co flag get set? Is there a critical time period between brake light switch "On" and a front wheel slip that sets a very low-co flag?**

h. **The last sentence of this paragraph is confusing as it states, "The start timing of pressure increase will be delayed most when the wheel speed becomes consistent with the reference speed (See the circles portion in the attached Appendix 9d, part 2.)" Based upon the previous sentence, it appears that brake pressure would rebuild at the time that the wheel speed matches vehicle reference speed. Explain in detail.**

Response 3

First of all, we will explain the ABS learning function. The purpose of this function is to switch the values of slip filter when specific surface (like a graveled road) is recognized by counter (to detect and count higher than designated acceleration/deceleration values). The learning function is not functioned to make the filtered values change in linear.

Response 3a

There is no special caution on testing of an ABS unit with a learning function. Any learned counter values will be reset to "0 (zero)" by turning off the ignition key or driving on a flat surface of the road for more than one (1) second without depressing brake pedal.

Response 3b

The aforementioned counter does not have any relation to ABS activation as described in the examples "for the rest of the ignition key cycle, for more than one brake application invoking ABS, for more than one 'build to depart, dump to recover' cycle during an ABS stop" of the question. As stated in "Response 3-a" above, the set-up slip ratio to trigger

ABS control will be reset to "0 (zero)" by turning off the ignition key or driving on a flat surface of the road for more than one (1) second without depressing brake pedal. On the other hand, the set-up slip ratio values will remain unchanged while the brake lamp switch is being turned on.

Response 3c

The slip ratio that "triggers ABS control" of each of the front and rear axles will change by a pair of each left and right side.

Response 3d

As stated in Response 3-a above, any learned counter values will be reset to "0 (zero)" by turning off the ignition key or driving on a flat surface of the road for more than one (1) second without depressing brake pedal. These are the conditions that sets the lowest wheel slip ratio possible for testing. The condition before learning raised wheel slip ratio to "trigger ABS control" is the lowest wheel slip ratio possible for testing.

Response 3e

20 ABS stops on wetted Jennite will not change the ABS performance.

Response 3f

The counter values that raise wheel slip ratio to "trigger ABS control" will be caused to increase when the absolute values of wheel acceleration/deceleration was either of the following cases:

- When the reference speed is smaller than 70km/h, the absolute value of wheel acceleration/deceleration is greater than 0.8G.
- When the reference speed is equal or greater than 70km/h and it is smaller than 120km/h, the absolute value of wheel acceleration/deceleration is greater than 1.2G.
- When the reference speed is equal or greater than 120km/h, the absolute value of wheel acceleration/deceleration is greater than 2.0G.

Response 3g

There is no flag set for a very-low-co . A very-low-co road surface is determined by the G sensor value when it was smaller than 0.32G. The ABS control unit only monitors the G sensor value as to whether it satisfied this condition in every calculation cycle.

Response 3h

In case the wheel acceleration is large, the hydraulic pressure will start to increase before the wheel speed reaches the reference speed. If the wheel acceleration is small, the timing where pressure starts increasing will be delayed, but even in this case, the hydraulic pressure will start to increase at the time when the wheel speed is the same as the reference speed at the latest. Accordingly, Subaru already explained "when the wheel speed becomes consistent with the reference speed" as the case that "the start timing of pressure increase will be delayed most" in our previous response in April 2004 (see Appendix 3h).

4. After our review of Subaru's response to Request No. 9g of EA-IR, the diagram attached to Subaru's response as Appendix 9G and titles "ECU Internal Circuit diagram" (diagram), we have the following questions:

- **a. The diagram shows an input for "AT only" [near "C208" on drawing], what is the reason/function for this item?**
- **b. The diagram shows an output for "AT only" [near "C501" on drawing], what is the reason/function for this item?**
- **c. The diagram shows an input for a single G sensor with the note "4WD only" [near "C08" on drawing]. Is it not true that all Subaru's are AWD all the time?**
- **d. The diagram shows only one G sensor, while response 9a says, "compensated according to the value of front/rear G sensor." Explain in detail.**

Response 4a

This terminal makes a feedback of the signal of 4-b to the ABS ECU. It monitors if the signal is outputted correctly.

Response 4b

This terminal outputs a signal to automatic transmission whether ABS is activated or not.

Response 4c

FHI manufactures front wheel drive (FF) specification vehicles for other markets which are not introduced in U.S. market. The diagram shows the note "4WD only" because it affects only "AWD" specification vehicles.

Response 4d

During preparation of this response, Subaru realized that the term "front/rear G sensor" was misinterpretation against original term in Japanese. The correct term in English is "longitudinal G sensor". Accordingly, there are no dual sensors (front and rear sensors). There is only one sensor.

5. Are there any cautions on ABS testing of Subaru's that may not be obvious? For example, one manufacturer has told us that the ABS self-test conditions could interfere with ABS testing since the vehicle needed to exceed 15 mph for more than 10 sec, without a 0.9 g wheel acceleration or deceleration (note the exact numbers have been changed). Specifically, the manufacturer warned us that if a vehicle were started, raced to 40 mph, and brake tested, the ABS might not have been fully operational. What are the Subaru ABS self test initiation speed, duration, limitations, etc?

Response 5

There are no cautions on ABS testing of Subaru vehicles. The ABS system starts to operate normally after the ABS warning light comes on when the ignition switch is turned to the "ON" position and then the ABS warning light goes out. Please note, however, that the ABS system will not operate when the vehicle speed is below approximately 6mph as indicated in Subaru Owner's Manual.

Subaru Conclusions

As ODI is well aware, this investigation has been going on for more than a year, and despite the best efforts of Subaru and ODI, not only has no safety-related defect been identified, but the condition a few owners have claimed to have experienced has not been replicated reliably.

It is well understood by the industry (although not by all ABS vehicle owners/drivers, unfortunately) that ABS vehicles do not necessarily exhibit shorter stopping distances under all driving situations. Such is NOT the reason for fitting ABS to a vehicle. The primary benefit of ABS is to permit better vehicle control during stopping maneuvers (by preventing wheel lock-up, and thereby affording greatly increased steering capability). Of course, another significant advantage is the skid resistance provided under low coefficient of friction conditions.

Throughout these past 13 months, Subaru, as always, has cooperated with NHTSA, not only responding candidly to each of ODI's inquiries, but conducting its own testing and investigation (including, among other things, the buy-back of vehicles for testing of customers who had claimed to have experienced the phenomenon). Notwithstanding this, Subaru has seen nothing to change its opinion that the customer complaints are largely the result of the aggressive driving patterns frequently employed by WRX owners/drivers (performance cars are purchased and driven by persons expecting to utilize that performance), coupled with the stiff suspension of the WRX.

As NHTSA is also aware, few of the "complainants" have, in fact, experienced the phenomenon themselves. Many of the complaints to NHTSA were generated solely as a result of the Subaru Impreza Owners Club web site in support of the few other drivers who may have experienced the unexpected activation of ABS during hard braking on a rough road surface. Although such ABS operation may have been a surprise to some of those drivers, it should not come as a surprise that ABS activates during hard braking on a rough surface where wheel hop (more common with a stiffly-spring vehicle, such as the WRX) is sometimes interpreted by the ABS computer as a skid, resulting in ABS activation. In this respect, the WRX ABS would perform no differently than that of another similarly-sprung vehicle under the same driving conditions (hard braking on certain rough road surfaces).

Subaru continues to maintain that, not only is there no safety-related defect (an "unreasonable risk of accident, injury or death") in the WRX ABS, the WRX system functions as does ABS on other vehicles (Subaru and competitive vehicles).

As always, Subaru will continue to monitor this situation and will advise NHTSA should there be any new developments.

If NHTSA has any questions concerning this issue, please contact me at (856) 488-8644 or Gerry Plante at (856) 488-3226.

Sincerely,

FUJI HEAVY INDUSTRIES U.S.A., Inc.

Don Bearden, Director
Government Relations

cc: Office of Chief Counsel

APPENDIX 1

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APPENDIX 3h

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