Innovative Quieter Aspirator Design for In-car Temperature Sensor

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Abstract- **Automotive vehicles use aspirators to sense in-car temperature for controlling thermal comfort. The aspirator noise at the sensor end located on dash can be unacceptable and therefore an additional muffler is used between the sensor and the aspirator. An innovative aspirator design was developed to replace the aspirator and muffler by a one-piece design. This new concept was designed to meet the noise performance targets while making it easy to manufacture, while meeting the airflow targets of the current production two-part aspirator and muffler design. The new design incorporates the change in airflow direction to address the customer concern.**

Keywords- Muffler; Noise; Airflow; Aspirator; Automotive

I. INTRODUCTION

Many vehicles use an automatic temperature sensor mounted on the dash (IP or Instrumentation Panel) to sense the vehicle interior temperature for controlling occupant climate comfort. One type of design requires airflow over the sensor to correctly measure the interior vehicle temperature. This suction airflow over the sensor is produced by various means. The present study deals with a widely used aspirator design that draws/sucks cabin air by means of the Venturi effect caused by discharge airflow in the HVAC module. Such a design has the inherent drawback of transmitting HVAC module noise [1, 2, 3] and aspirator-generated flow noise to the sensor airflow opening mounted on the dash (via the connecting tube between the sensor and aspirator). In one application, this caused a customer noise complaint due to higher noise levels at frequencies above 2 kHz. This required a separate muffler to be placed between the aspirator and the sensor to reduce this noise. This two-part aspirator and muffler design is now replaced by a new innovative one-part design that is easier to manufacture. This paper presents the airflow and noise test results of this new design compared to the current design.

II. NEW DESIGN VS. CURRENT ASPIRATOR AND MUFFLER

Figure 1a shows the current aspirator design mounted on an HVAC module. A small quantity of airflow from the blower diffuser exit side of the module is discharged through the aspirator. The Venturi effect in the aspirator creates suction in the direction indicated in the figure. The new design is also shown for reference.

Figure 1b compares the assembly of aspirator, tube, muffler and sensor for the current design to the aspirator, tube and sensor assembly of the new design. The new design does not require a separate muffler. The muffler was designed as a part of aspirator based on muffler principles of [4-6].

Figure 1c shows the production tooled version of the new replacement design [1] incorporating the changes in airflow direction to address the customer concern - the discharge side moved up slightly. Top cover, bottom cover and assembly views of this design are included.

Figure 1d shows the new design without top cover showing aspirator flow and muffler. When mounted on high pressure location of the HVAC module (typically blower diffuser section), high pressure from the HVAC causes flow to go through two channels as shown in this figure (flow shown by black arrows). The ventury/constriction at the two discharge channels leads to high velocity jet for the flow from HVAC module creating suction at the inner channel leading to suction flow as shown by red color arrows.

A. Current Production Design

The current manufacturing process requires two separate injection molds, each for the muffler and aspirator assemblies. Once injection molded, the assembly process for the muffler requires a piece of foam be inserted between two housing pieces which are then “spin welded” together to form an air-tight seal. The aspirator is also a two-piece housing design that requires the use of a “heat stake welding” process to attach the two pieces together. The aspirator and muffler assemblies are then attached to two separate pieces of corrugated tubing and snapped into place on the HVAC assembly.

B. New Replacement Design

The new manufacturing process requires only one injection mold to produce the combined aspirator/muffler design. Once injection molded, the assembly process requires the cover be assembled to the body with the use of a fixture to apply a force evenly to the one way snap features located around the periphery of the part. Another manufacturing advantage of the new design is the ability to use only one piece of corrugated tubing since the new design incorporates the aspirator and muffler into one piece (as noted above, the current design requires two pieces of corrugated tubing.). The attachment strategy for the aspirator to the HVAC assembly is the same for the new design and current production design.

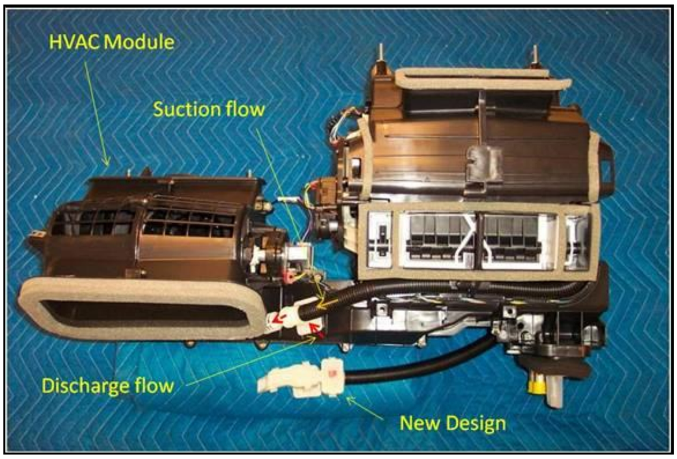

Fig. 1a HVAC module with current aspirator assembly (new design shown for reference)

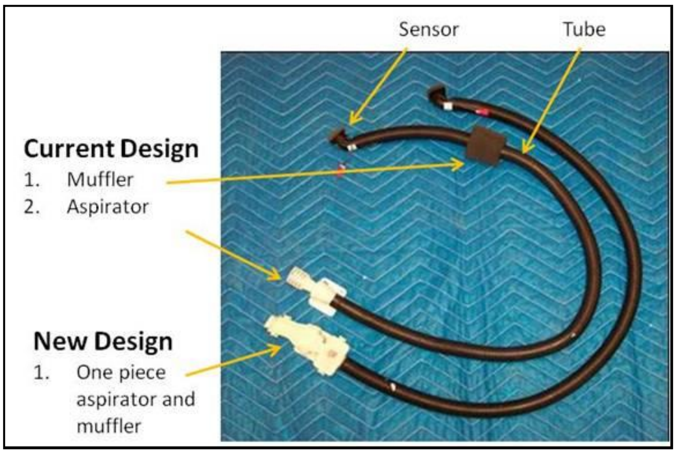

Fig. 1b New vs. current aspirator assembly

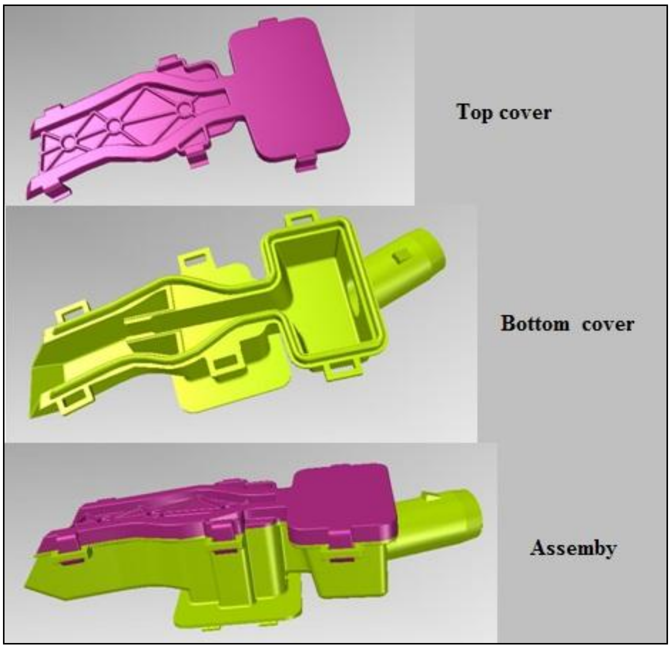

Fig. 1c The new aspirator design incorporating the changes in airflow direction

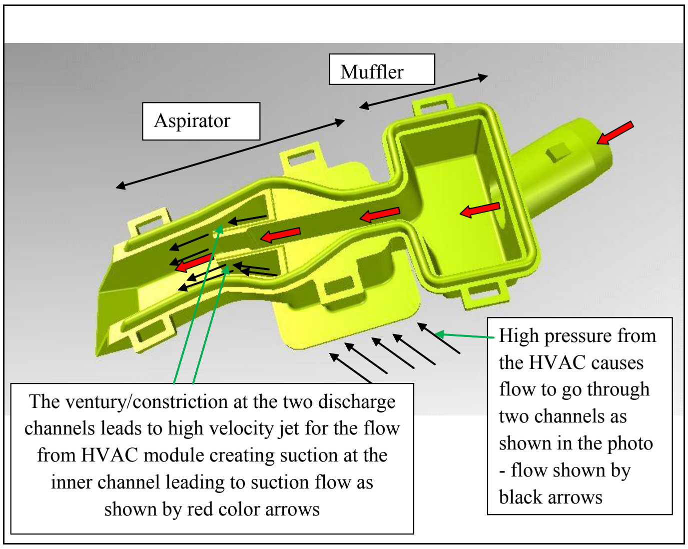

Fig. 1d The new design without top cover showing aspirator flow and muffler

III. AIRFLOW AND NOISE MEASUREMENTS AND TEST RESULTS

In the aspirator design, it is essential to consider three parameters for quantifying the aspirator performance, namely: i) discharge (wasted) airflow, ii) suction airflow and iii) aspirator noise level near the sensor end. The discharge airflow is ambient air from the blower diffuser section – this airflow is not thermally conditioned. This wasted airflow must be kept to a minimum because this flow in the passenger compartment can lead to occupant thermal discomfort. The aspirator must also be designed so that the suction airflow over the temperature sensor is sufficient even at the lowest blower speed. The noise emitted by the aspirator sensor end is important because this results in noise emissions from the dash-mounted sensor that can affect the vehicle occupants.

The objectives for this new replacement aspirator design were i) to exhibit the same or lower discharge airflow, ii) to exhibit the same or more airflow over the sensor and iii) to exhibit the same or lower noise levels compared to the current production design.

A. Discharge Airflow Tests

The quantity of discharge airflow at the aspirator exit was measured using an airflow tunnel. Measurements were carried out in two modes: Panel full cool mode and floor full hot mode; and at 4 blower voltages, namely: 4, 6, 9, 12 V dc.

Figures 2a and 2b show the discharge airflow as a function of blower voltage with HVAC module operating in panel full cool and floor full hot modes, respectively. The solid line shows the flow rate (l/s) versus blower voltage (V dc) for the current production design and the dotted line shows the same relationship for the new replacement design. It can be seen that the new design reduces the waste discharge airflow at a given voltage significantly compared to the current production design, and therefore meets the discharge airflow requirement for the current production design.

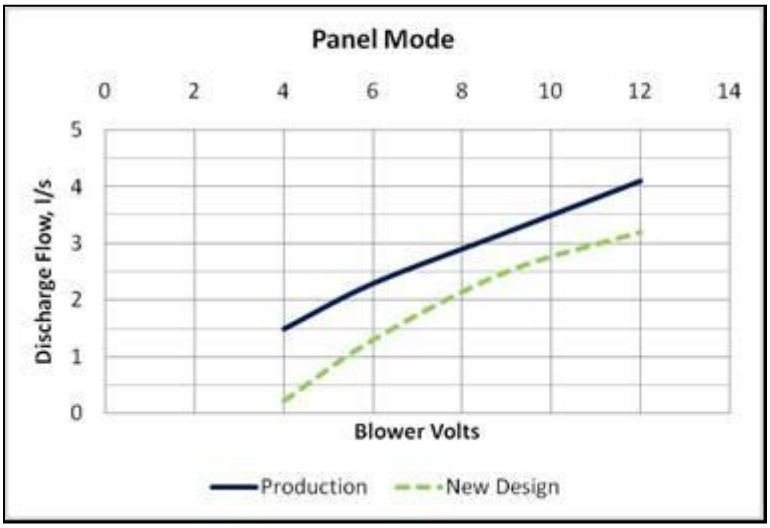

Fig. 2a Discharge airflow with HVAC module in panel full cool mode

Fig. 2b Discharge airflow with HVAC module in floor full hot mode

B. Suction Airflow Tests

The quantity of suction airflow is very small and is hard to measure accurately. Therefore, a manometer was used to measure the suction pressure near the aspirator tube junction, which is proportional to the suction airflow. Measurements were carried out in two modes: Panel full cool mode and floor full hot mode; and at 4 blower voltages, namely: 4, 6, 9, 12 V dc.

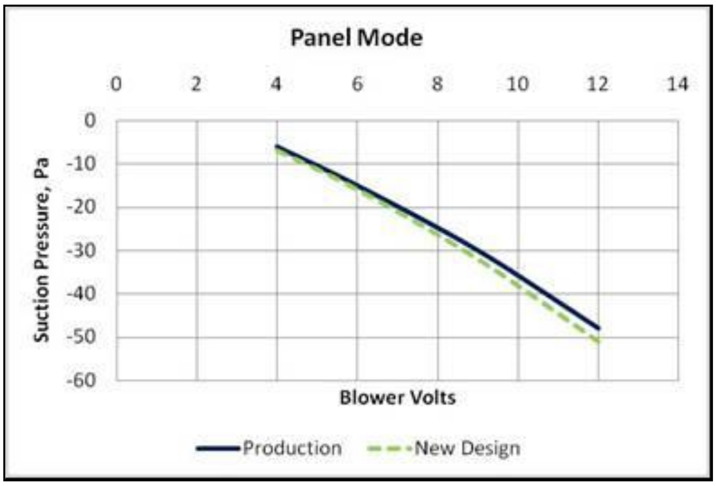

Fig. 3a Suction Pressure near aspirator with HVAC module in panel full cool mode

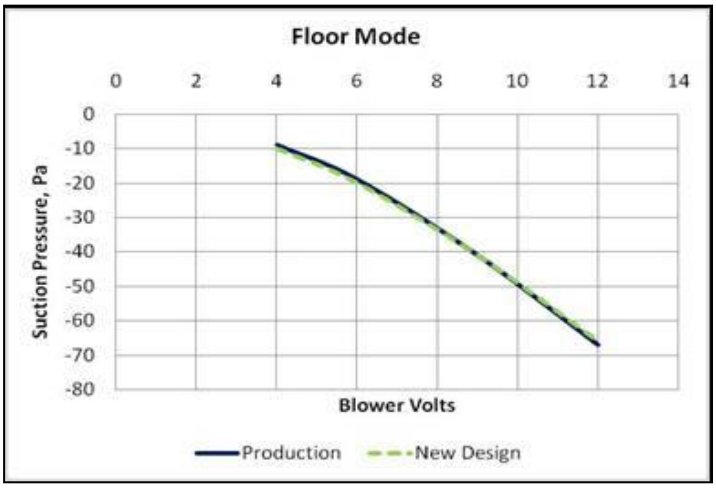

Fig. 3b Suction Pressure near aspirator with HVAC module in floor full hot mode

Figures 3a and 3b show the suction pressure as a function of blower voltage with the HVAC module operating in panel full cool and floor full hot modes, respectively. The solid line shows the suction pressure (Pa) versus blower voltage (V dc) for the current production design and the dotted line shows the same relationship for the new replacement design. It can be seen that the new design provides the same or greater (negative value) suction pressure at a given voltage compared to the current production design. This means that, at a given voltage, the new design exhibits the same or higher airflow over the sensor compared to the production design, and therefore the new design meets the suction airflow requirement for the current production design.

C. Muffler Equivalent Noise Reduction Tests

The new aspirator muffler was designed to have the same muffler area expansion ratio as the current production muffler (the expansion ratio is the ratio of the cross sectional area of the muffler chamber to the cross sectional area at the open ends). For the current production muffler design, the value of this expansion ratio is 6.6, which results in calculated transmission loss (TL) of about 10 dB. The production design uses a conventional muffler arrangement separate from the aspirator assembly. Therefore, this conventional muffler could be characterized in terms of TL fairly readily. However, the new design with the muffler integrated in the aspirator assembly made true TL measurements impractical.

Instead of pursuing TL measurements, a more practical check of the equivalent noise reduction performance was performed on the production muffler and the new aspirator muffler to confirm the new design provides equivalent noise reducing properties. This equivalent noise reduction check was conducted by mounting the “noisy” module-side of the muffler under test to a source box containing a loudspeaker emitting pink noise. Inside the box, a microphone was located 54 mm from the muffler opening. Outside the box, a plexiglass tube (490 mm long, 60 mm diameter and 5 mm thick) was mounted to the “quiet” side of the muffler, with a microphone located in the wall of this tube at 270 mm from the muffler opening into the tube. The 1/3 octave noise reduction values of the muffler under test were found by calculating the difference between the 1/3 octave sound pressure level values measured at the two microphones. The calculated noise reduction values for the two muffler designs are shown in Fig. 4.

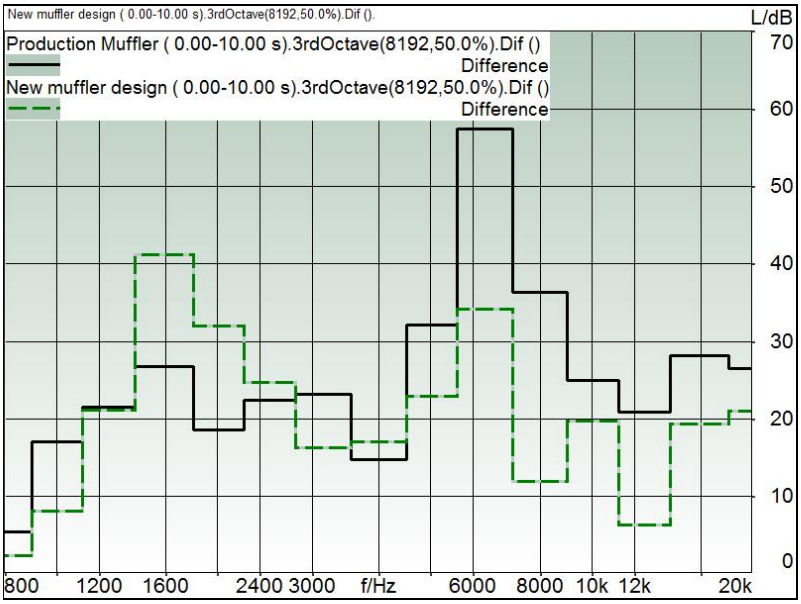

Fig. 4 Noise reduction measurements for the production and the new mufflers

Figure 4 shows that both the two mufflers provide a minimum of at least 10 dB of noise reduction in each 1/3 octave band in the frequency range of 1200 to 10,000 Hz. Note that the higher noise reduction performance of the production muffler above 4000 Hz is due to an acoustic foam lining inside the expansion chamber. The new muffler was designed not to include foam lining for cost reasons.

As can be seen in the module-level tests of these two muffler designs discussed in the next section, both designs exhibit sufficient noise reduction performance to provide acceptable reduction of the aspirator-transmitted noise. The length of the new muffler design was optimized through trial and error tests on the module level with different muffler lengths until equivalent noise levels were achieved above 1000 Hz to mimic the production muffler design (this was done during the module tests discussed in the next section).

D. Module-Level Noise Tests

Figure 5 shows the noise test setup in a semi-anechoic room. The aspirator tube and sensor end are visible at the front of the tested HVAC module (from a current production SUV).

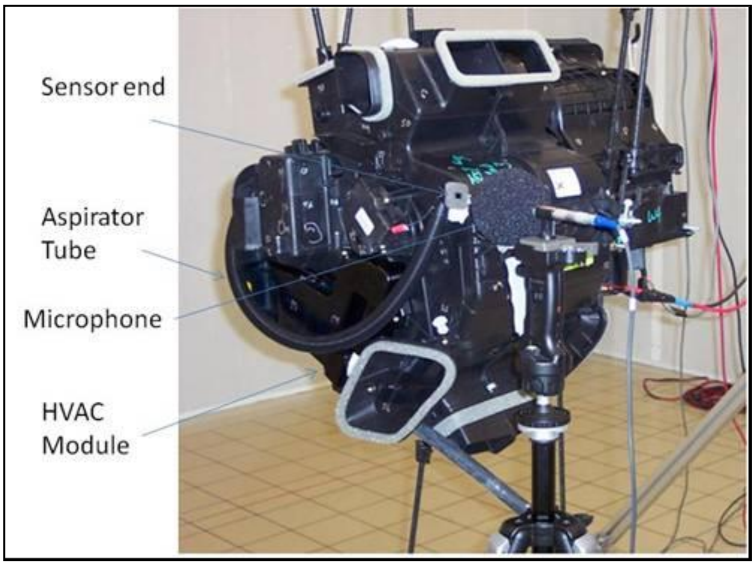

Fig. 5 Aspirator noise test setup

The aspirator is mounted on the rear side of the HVAC module and not visible in Figure 5 (see Figure 1a). In a more typical HVAC noise test, a measurement microphone would be located at the driver's ear with respect to the HVAC module. However, the aspirator noise at the driver's ear location is often sufficiently masked or interfered by other HVAC module noise so that reliable A-B comparisons would be difficult. Therefore, for these aspirator noise tests, one microphone was placed only 10 cm from the sensor end to capture primarily the aspirator-related noise levels emitted near the sensor end and exclude other noise generated by the blower and by airflow through the HVAC module. The noise measurements were carried out in two modes: Panel full cool mode and floor full hot mode; and at 4 blower voltages, namely: 4, 6, 9, 12 V dc.

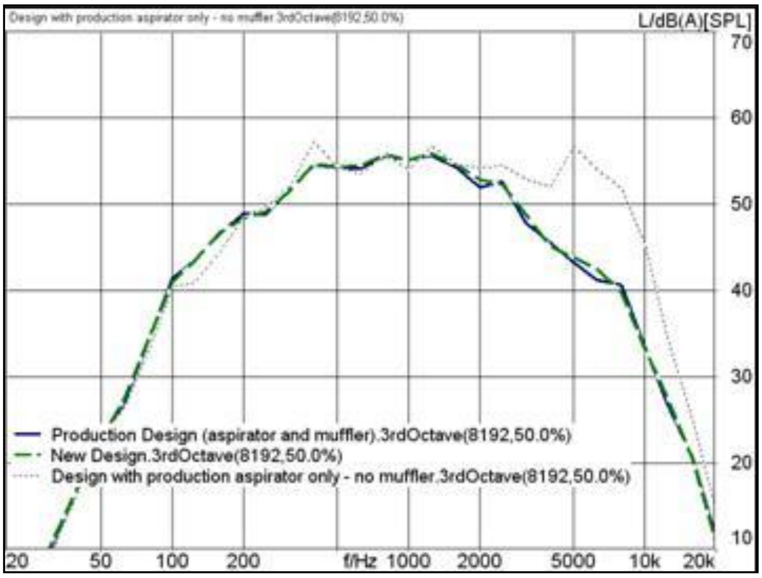

Fig. 6a - Noise spectra near sensor end with HVAC module in panel full cool mode, 12Vdc

Figures 6a and 6b compare the noise spectra at 12V dc with the HVAC module operating in panel full cool and floor full hot modes, respectively. The solid line shows the noise spectra for the current production design and the dashed line shows the spectra for the new design. It is seen that the new design exhibits very similar 1/3 octave band noise levels compared to the production design at 12 V dc (similar results were also obtained at the lower test voltages.) Therefore the new design meets the noise requirement of the production design.

It is seen in Figures 6a and 6b that the current production design muffler is effective above 1 kHz (compare the solid gray line for the production design without muffler to solid black line for the production design with foam lined muffler). The new replacement design aspirator (which incorporates the muffler function in the aspirator body) meets the noise performance of the current production design without requiring a separate foam lined muffler. These are practical results as compared to the noise reduction test results described earlier in Section III C and were used in optimizing the length of the new muffler without foam lining.

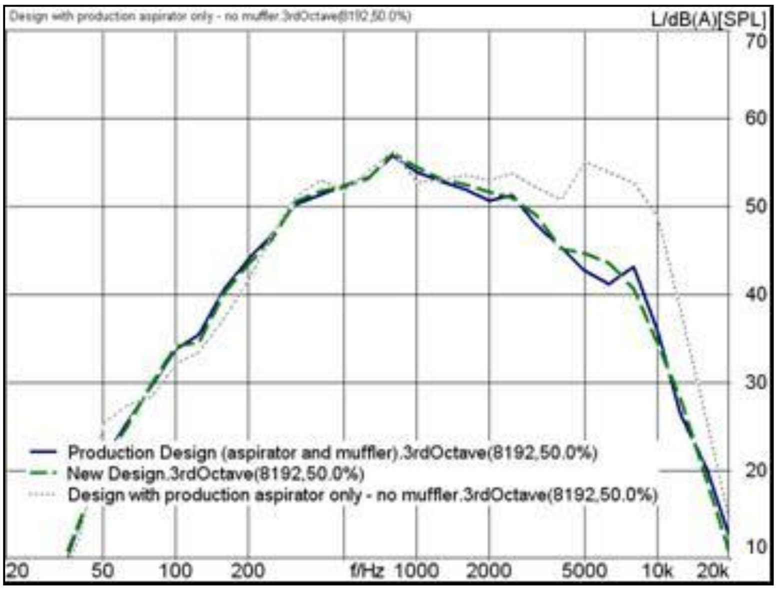

Fig. 6b - Noise spectra near sensor end with HVAC module in floor full hot mode, 12Vdc

IV. CONCLUSIONS

The present study deals with a widely used aspirator design that draws/sucks cabin airflow by means of the Venturi effect caused by discharging HVAC module flow. In one application, this caused a customer noise complaint requiring a separate muffler part between the aspirator and sensor to reduce this noise. A new innovative aspirator design was subsequently developed that replaces the two-part aspirator and muffler with a single part that meets or exceeds the airflow and noise performance of the two-part current production design while improving the ease of manufacturing. This new design included the change in airflow direction to address the customer concern.

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