Lightweight Filler Neck Hose for Reducing Environmental Load

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For automotive fuel piping, we have been working on the reduction of fuel permeation to comply with regulations for hydrocarbon evaporation including low emission vehicle standards in the North America. Concurrently, in order to comply with the tightening CO_2 emission control, we have also been working on the reduction of CO_2 emissions by improving fuel efficiency through vehicle weight reduction. For this purpose, we have promoted the replacement of rubber hoses used for filler neck piping with those made a low fuel permeation material, and the metal filler pipe with a resin pipe. The replacement to the resin filler pipe involved the development of modules that consist of filler pipes and hoses. This paper describes these development efforts.

Keywords: regulations for hydrocarbon evaporation, weight reduction, fuel tank, filler piping

1. Introduction

Rubber hoses used for automotive fuel piping have been changed to lamination structures using low fuel permeation materials to prevent fuel permeation*[1] from hose wall surfaces in association with increasingly tightened regulations for hydrocarbon evaporation.*[2] The filler hose specifications have undergone remarkable evolutions in accordance with the requirements of regulations, for example, a double-layer rubber hose with FKM (fluororubber) used as a barrier layer evolved from NBR-PVC (rubber with polyvinyl chloride (PVC) blended in nitrile rubber (NBR)) single-layer rubber hose, a resin/rubber composite type with thin film resin of PA11 (polyamide 11) or PVDF (polyvinylidene fluoride) affixed to the hose inner surface, and a resin corrugated type consisted of a laminated tube of ETFE (ethylene-tetrafluoroethylene copolymer) and PA12 (polyamide 12).

In the meantime, in recent years, development of lightweight products aimed at improved fuel efficiency has been taking place. We have been engaged in resinification of filler pipes and developed an integral type resin filler neck hose integrated with a filler hose.

2. Technological Trend and Current Issues

2-1 Legal trends of each country

With the application of regulations for hydrocarbon evaporation in the State of California, U. S. A. in 1996 as the opener to respond to environmental issues, similar regulations have been applied in each area[(1)](Table 1). They are regulations to prevent destruction of the ozone layer attributable to hydrocarbons, nitrogen oxides, etc. contained in evaporative fuel and emissions that are discharged from vehicles into the air. In recent years, evaporative hydrocarbon emissions present a serious problem particularly in North America and China where a large number of vehicles are sold, and regulations have been tightened. In Japan, Europe, and Asian countries, too, regulations concerning hydrocarbon evaporation are in force, and are expected to be tightened in the similar manner.

Table 1. Regulations for hydrocarbon evaporation

Region	Regulation name	Applicable year
U.S.A. (California)	LEV I	Since 1996
	LEV II	Since 2000
	LEV III	Since 2015
China	National VI Emission Standards	Since 2018
Japan	Post New Long Term Standards	Since 2009
Europe	EURO6	Since 2015
Asia	EURO4	Since 2017

2-2 Function requirements for fuel filler hose

The fuel filler hose connects the filler pipe to the fuel tank in the piping for refueling from the filler neck to the fuel tank (Fig. 1). The required functions include basic performance including seal efficiency to prevent fuel leakage from occurring, pull-off resistance provided for impact at the time of the vehicle crash, flexibility under the low-temperature atmosphere, and others. In addition, flexibility to meet pipe routing when a vehicle is assembled and filler pipe insertion operability are required. Furthermore, in order to meet requirements of regulations for hydrocarbon evaporation, low fuel permeability is needed, and the required functions are varied by the fuel identity and types of applicable laws and regulations, and filler hose material and structure are suitably selected.

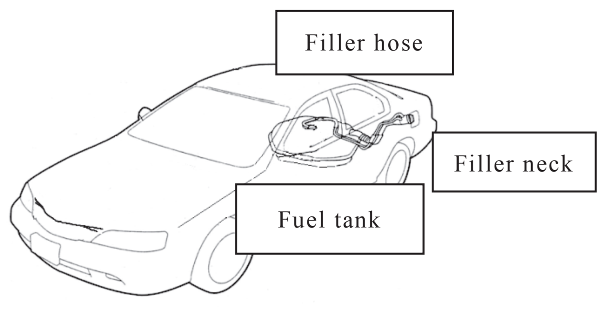
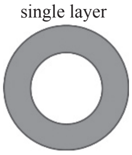


Fig. 1. Site where filler hose is used

2-3 Material changes of filler hose

Regulations for hydrocarbon evaporation were targeted at alcohol blended fuel to reflect fuel market trends. The filler hose became the laminated structure using fluoro-rubber with outstanding low-fuel permeation from NBR-PVC rubber single layer structure. When the alcohol blended fuel was adopted, a hose with dissimilar materials composite structure was developed with thin-film fluoro resin laminated on the rubber hose inner surface (Table 2).

Table 2. Change of regulation requirements and rubber hose material

Regulations	Before responding to regulations	Response to LEV I	Response to LEV II
Target permeation amount	-	200 mg/day/hose	50 mg/day/hose
Structure	NBR・PVC single layer 	FKM/NBR・PVC 	PVDF/NBR・PVC 

In North America, LEV III has been applied since 2015 and the fuel permeation amount was more and more stringently regulated. A seal structure became necessary to prevent even a slight amount of leak from fuel tank as well as joined surfaces with the filler pipe. A quick connector that could join them in one operation to absorb variations in component accuracy and in operations at assembly plants was developed (Fig. 2).

Furthermore, needs arose to reduce fuel permeation from joined portions by achieving module designs integral with counterpart components to be assembled.

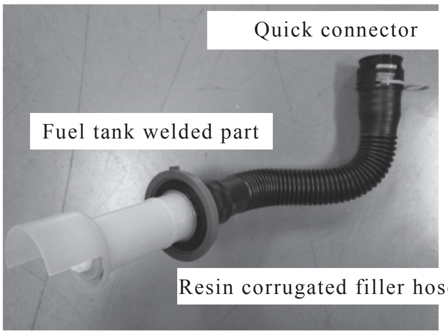


Fig. 2. Corrugated filler hose

2-4 Issues on fuel tank peripheral components

To extend the regulation product service life, measures against rust of steel components became a technological problem, too. At the same time, weight reduction became the issue to meet requirements for low fuel consumption, and steel fuel tanks were replaced with resin tanks by blow molding (Fig. 3). In the meantime, filler pipe specifications were changed from steel pipe to stainless steel pipe as a result of increasingly stringent requirements for rust-prohibition in North America.

In Europe, resin tanks were mainstream and the resin blow-molded filler pipe was directly welded to the resin tank. In this regard, however, in North America, flexible filler hose was needed in order to absorb impact at the time of vehicle crash, and resin filler pipe was unable to gain popularity because flexible bellows were unable to be formed with the resin blow-molded filler pipe as adopted in European vehicles.

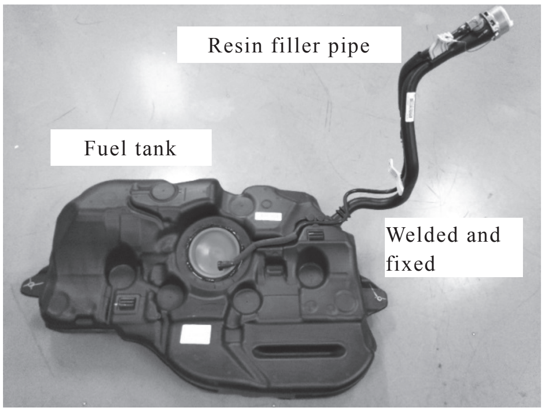


Fig. 3. Application example of resin blow-molded filler pipe

The resin blow-molded filler pipe provides a large packing form when welded to the fuel tank, resulting in poor transport efficiency, and since it could not be deformed when mounted to vehicles, the assembly job sequence needed to be greatly changed and its adoption did not gain popularity in Japanese carmakers.

3. Developed Integral Type Resin Filler Neck Hose

3-1 Weight reduction concept

From the viewpoint of environmental issues, development of fuel-efficient vehicles became still more active. While requirements of weight reduction of components increased severity, we focused on the resinification of filler piping. The resin blow-molded filler pipes adopted in Europe have variations in wall thickness at the bent portion, and to secure the minimum wall thickness, the overall thickness must be increased and this was not effective from the viewpoint of weight reduction. We undertook development of resin filler pipes using extrusion-molded tubes that are able to be molded in the uniform wall thickness. In addition, corrugated tubes were adopted to secure flexibility when pipes are mounted to vehicles, and a 40% reduction rate was contemplated. To lower the fuel permeability, a welding structure with the fuel tank was adopted for the purpose of reducing the number of joined portions (Fig. 4).

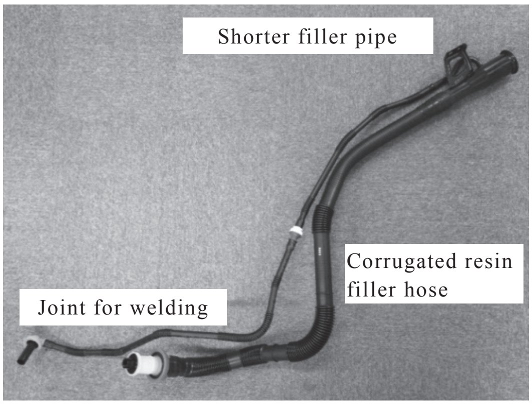


Fig. 4. Integral type resin filler neck hose

3-2 Tube material configuration and thickness configuration

A laminated construction made of HDPE (high-density polyethylene) and EVOH (ethylene vinyl alcohol copolymer) was adopted for the tube body. The use of the material same as that of fuel tanks ensures the reliability in material deterioration against the use environment, and the use of EVOH as a barrier layer for fuel permeation achieved the material configuration that complied with LEV III, the severest regulations of North America (Table 3).

Table 3. Regulation requirements and target permeation amount of developed filler neck hose

	Existing filler neck hose		Developed hose
Regulations	Response to LEV I	Response to LEV II	Response to LEV III
Target permeation amount	200 mg/day/hose	50 mg/day/hose	10 mg/day/hose
Structure	FKM/NBR・PVC	PVDF/NBR・PVC	HDPE/EVOH/HDPE

In order to suppress the flow resistance when refueling, the smooth pipe must be bent to form the filler pipe. HDPE is crystalline resin that provides low glass transition temperature. HDPE provides a disadvantage in that even applying heat during bending and forming just provides a set and the crystallized form remains unchanged, and reheating causes the bent angle to return to the original angle. Setting excessively big wall thickness results in a large bending-back amount and a big clearance must be secured to avoid interference with peripheral components. In contrast, excessively thin wall thickness generates flex wrinkles at the time of bending and forming. To secure bending formability, the wall thickness was set in the range of 2 to 2.8 mm.

3-3 Fuel permeability

The fuel permeability is able to be adjusted by the EVOH thickness. EVOH is the material with extremely little fuel permeation, and it is satisfactory if it does not cause layer breakage. The target fuel permeation amount from the filler tube is 10 mg/hose or less, and 4 mg/hose was actually measured, and the target was achieved (Fig. 5).

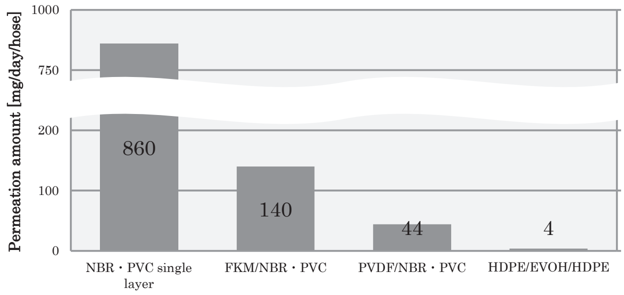


Fig. 5. Comparison between hose material configuration and fuel permeation amount

3-4 Reduced number of joined portions

Conventionally, a resin tube was joined to a metal pipe by the use of a connecting component called a quick connector, with an O-ring used as the seal member. However, the quick connector applied a filler pipe size (outside diameter: around 35 mm) has a large outside diameter. In the case of the filler piping that was routed as if it threaded its way through clearances between inner fender and suspension arm motion ranges, the connections were unable to be freely laid out in order to secure clearance to prevent interference, and there were big limitations from the viewpoint of designs (Fig. 6).

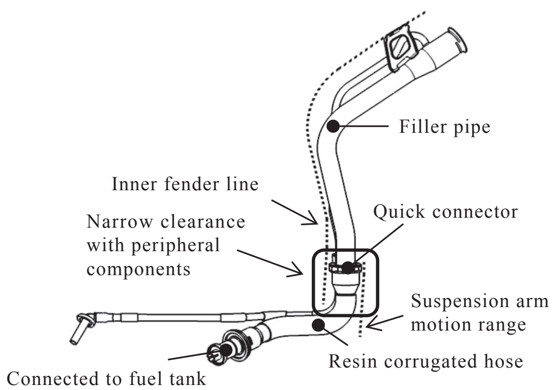


Fig. 6. Piping example using conventional resin filler hose

In the present development of the integral type filler pipe, adopting a flexible corrugated tube eliminated the need of joining operation in the vehicle assembling process and abolished the quick connector. The connections between the filler pipe and the filler hose were able to secure the pull-out force and seal efficiency in spite of a simple component configuration, which was achieved by strongly fitting the filler hose to the filler pipe via elastic coating applied to the connections with the filler pipe and the filler hose. In the present development, a small diameter joined structure was achieved, with the filler pipe outside diameter increased only by the wall thickness of the corrugated tube, improving the degree of layout design freedom in the filler piping that does not like interference with peripheral components (Fig. 7).

In addition, elastic coating causes little changes in physical properties by selecting fluoro-rubber-based material even when inferior fuel or alcohol blended fuel is used, and deterioration with time of fastening performance is able to be suppressed.

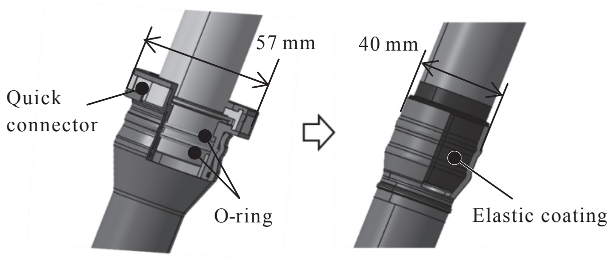


Fig. 7. Joining structure comparison with filler pipe

In the meantime, for the connection to the fuel tank, a structure to join the ICV joint[*3] press-fitted to the head end in the same manner as the conventional resin filler hose to the fuel tank by hot plate welding was adopted. In joining with a fuel tank using a rubber hose, the filler hose insertion amount and retainer clamp tightening state must be severely controlled because the fuel permeation at the joined portion must be controlled. Getting rid of assembly variations was able to secure the high seal efficiency against aging deterioration and at the same time, enabled the reduction in state control man-hours.

4. Conclusion

Conventionally, it was common practice to use a quick connector to join a resin tube to a metal pipe, but this method increased the number of components, exerting effect on the cost. The number of components was reduced by designing modules and a simple component configuration was employed to achieve a low-cost design. By adopting an extrusion-molded corrugated tube, padding was suppressed and flexibility was secured. The filler neck hose according to this development accomplished targeted compliance with the North American LEV III regulation, too, and achieved a 40% weight reduction as compared to the conventional piping using steel pipes.

Technical Terms

*1 Fuel permeation: The gasoline components are discharged through minute holes in the fuel hose, connections, and portions such as a fuel tank primarily comprising rubber, resin, and other materials. This symptom is called fuel permeation.

*1 Regulations for Hydrocarbon Evaporation: Regulations established to restrict the total discharge of the vapor from vehicles, which is the gas formed by evaporation of gasoline (also called gasoline vapor or evaporative emissions) and is discharged to the atmosphere in running, parking, or refueling, and becomes a factor for depleting the ozone layer.

*1 ICV joint: A check valve that suppresses fuel from back-flowing to the filler neck when the fuel tank is filled with gasoline to capacity.

Reference

(1) Risa Uchida, "Discharge of fuel evaporative hydrogen emissions from gasoline automobiles," JARAI Research Journal (2016)

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