New Fitting for Stainless Steel Flexible Gas Pipes

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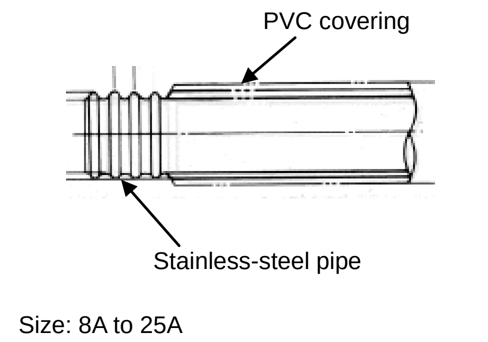
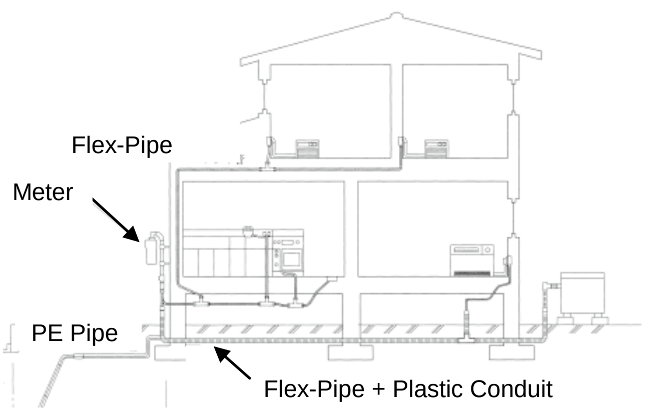
Background

The flexible stainless-steel gas pipe as shown in Figure 1, dubbed “flex-pipe,” is currently the de facto standard for in-house gas piping in Japan. This system provides not only superior earthquake resistance but is also easy to dimension and requires fewer threaded connections along the pipeline. Its shorter installation time and ability to be used in relatively narrow spaces have also contributed to its popularity.



(a) exterior view of flex-pipe



(b) example of in-house piping

Figure 1 Exterior view of flex-pipe and example of in-house piping in a single-family home

Since its introduction in the 1980s, flex-pipe has undergone numerous developments to make it easier to work with, lower costs, and increase safety, as shown in Figure 2. When they first appeared in 1984, flex-pipe specifications were not standardized throughout Japan, but this was changed in 1986 along with the addition of water-proofing of its fittings. Originally, the flex-pipe was designed to create an air-tight seal at the end using tools to tighten the connection, but the design was changed in 2002 to create a seal on the side, making it possible to connect fittings without the use of any tools. This “one-push” fitting has been in use for about eight years, but as a result of increasingly strict product liability obligations and more incidents of electric shock, these fittings must now be improved to make it easier to work with and more reliable.

Table1 The History of Fittings for Gas Flexible Pipes

Generation of Fittings	Timeline (1980 '85 '90 '95 '00 '05 '10 '15)	Sealing position	Note
1_{st}	'83 → For Spiral Flexible Pipes		
2_{nd}	'84-'85 → For Annular Flexible Pipes	End sufaface of Pipe	
3_{rd}	'86-'87 →		
4_{th}	'88-'93 →		Conpact
5_{th}	'94-'01 →		Conpact & Easy
6_{th}	'02-'09 →	Side surfave of Pipe	more Conpact & Easy
7_{th}	'10-The Present ----→		Workability & Reliability

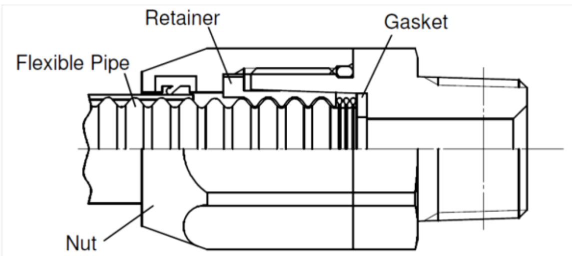


Figure2 Cross-section of former Flex-Pipe fitting (The 3_{rd} generation)

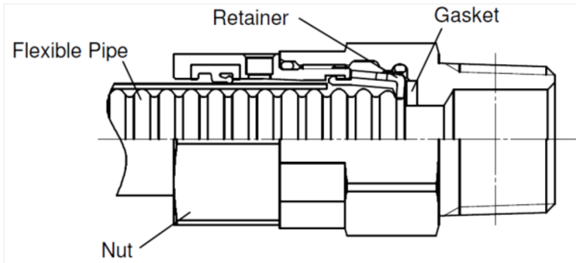
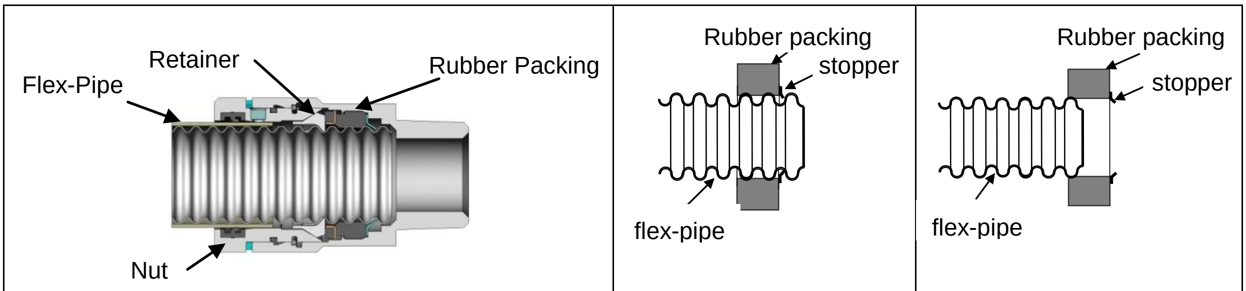


Figure3 Cross-section of former Flex-Pipe fitting (The 5_{rd} generation)

Figure 4 shows a cross-section of the flex-pipe inserted into a "one-push" flex-pipe fitting, with packing on the side surface of the flex-pipe creating an air-tight seal. Thus, even though it is rare, when the flex-pipe is not inserted to the proper position due to human error, as shown in (c), the flex-pipe may move when in use, resulting in a leak.



(a) Cross-section of the former fitting | (b) Flex-pipe completely inserted | (c) Not completely inserted

Figure 4 Cross section of former Flex-Pipe fitting (The 6_{th} generation)

Figure 5 shows the relationship between the long-term seal performance and the packing interference(surface pressure) when attached to a properly formed (not deformed) flex-pipe, and next to it the seal life for one that is deformed. When attached to a flattened pipe, the rubber packing becomes advanced the permanent deformation and the contact surface pressure is reduced, and on the side of the shorter diameter of the flattened pipe, the life span of the packing is shorter than that on a non-flattened pipe, increasing the chance of a gas leak with long-term use.

Thus, we redesigned the former flex-pipe fitting to improve its workability and reliability, creating a revolutionary new fitting with many new functions. The new design makes it easier to avoid installation errors (human error) such as incomplete insertion, and increases the tolerance for flex-pipe deformation (flattening), dents, or other surface imperfections.

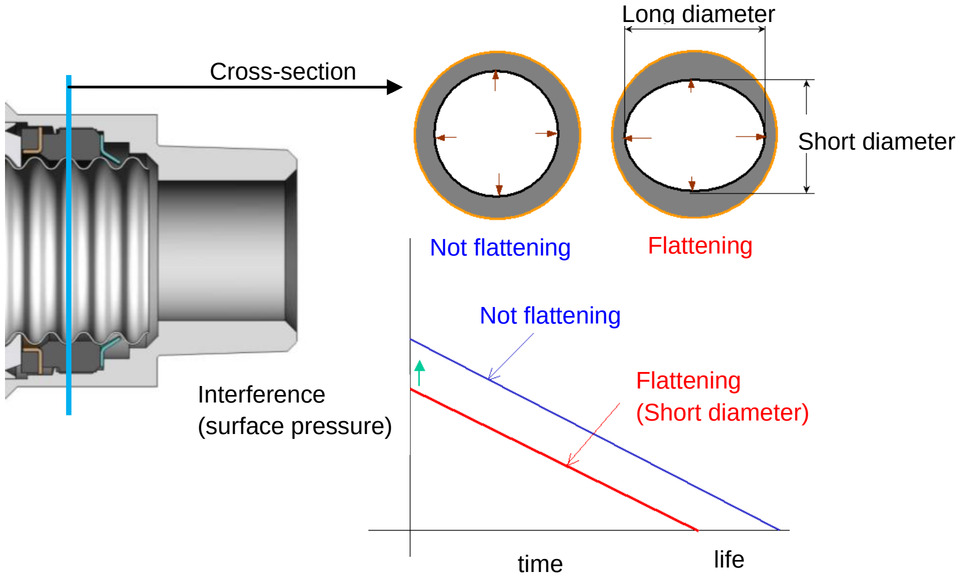


Figure 5 Long-term seal performance (life) and packing surface pressure

Aims

- To improve reliability by adding the indicator function to prevent the fitting from leaking caused by insufficient flex-pipe insertion.
- To reduce leakage caused by deformation and concave of corrugate shape profile, and to enhance the long-term sealing properties using a metal spring to improve the sealing properties.

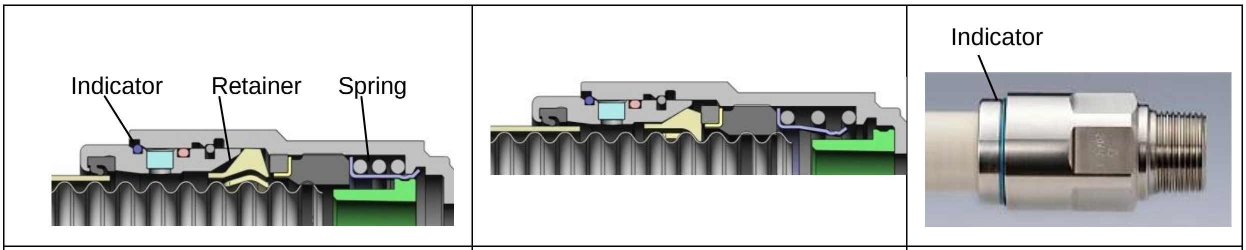
Methods & Results

(1) Addition of an indicator

To prevent incomplete insertion of the flex-pipe, the new flex-pipe fitting must have a fail-safe mechanism. There were two ideas for this. The first was to create a structure that would not allow the nut to be pushed when the pipe was not completely inserted. The other was to create an indicator that appears only when the pipe is properly inserted.

After designs and prototypes for both ideas were created and evaluated, the latter option was adopted. The indicator concept was adopted because the structure included an internal spring, and it was thought that this would give it better tolerance to flattening as described latter. In addition, the indicator would allow the workers as well as their supervisors to confirm that the work was done correctly.

Figure 6 shows a portion of the newly designed fitting. In Figure 6(a), the flex-pipe is not completely inserted and the retainer is not anchoring the flex-pipe yet, and thus it can be pulled out just by tugging on the pipe. In Figure 6(b), the retainer is securing the flex-pipe, and when pulling on the pipe to confirm that it is secured, the indicator shown in Figure 6(c) is exposed, providing a visual confirmation that the fitting has been properly attached.



(a) not finished	(b) finished	(c) appearance

Figure 6 Cross section and appearance of new fitting

(The 7_{th} generation)

Figure 7 shows an enlarged diagram of the indicator feature. After the retainer and flex-pipe are engaged, the worker can confirm that the pipe is properly inserted by pulling on it, which compresses a C stop ring and moves it from the central grove to the left groove, making the indicator appear.

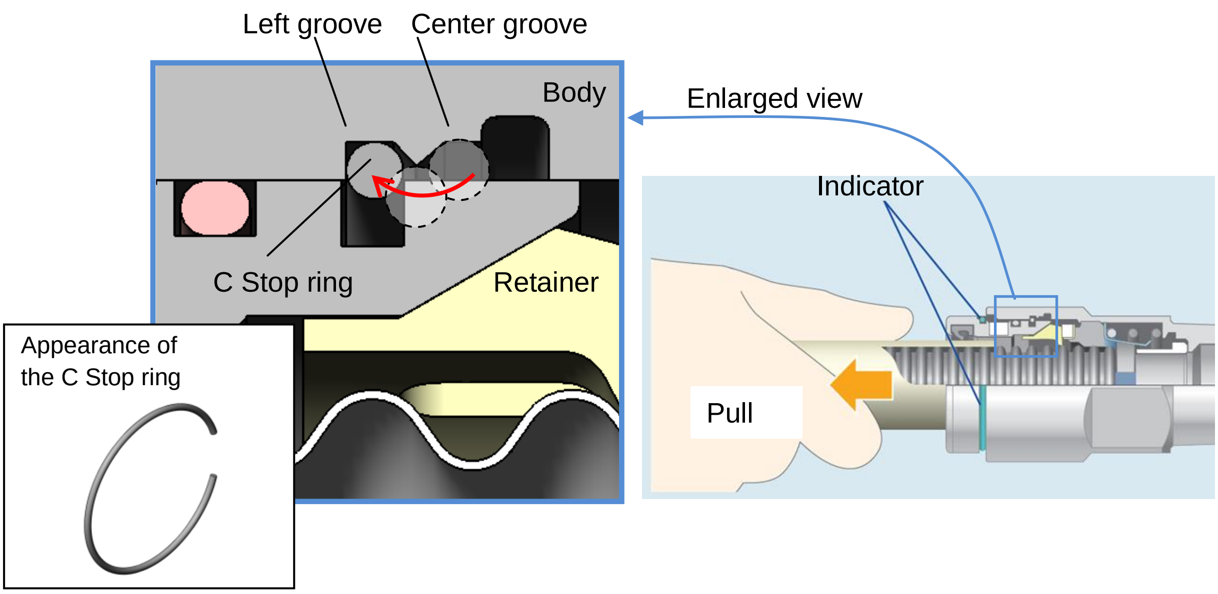


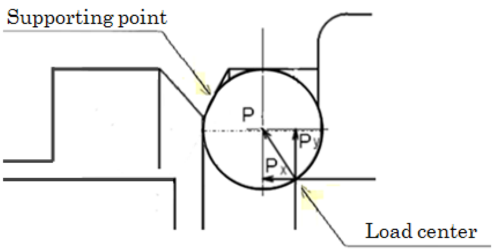
Figure 7 Indicator location of new fitting

The operational diagram for the newly developed fitting is shown in Figure 6. When the flex-pipe is not completely inserted and a confirmation test is performed by pulling on the pipe, the pipe comes out without moving the nut that contains the indicator. In contrast, when it is properly inserted, the flex-pipe and nut move together to expose the indicator.

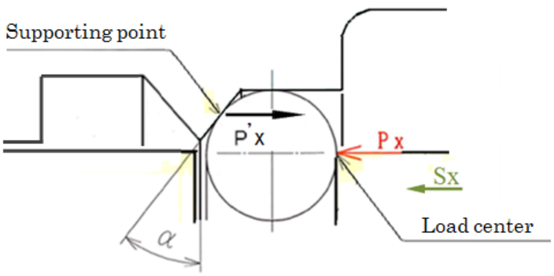
Figure 8(a) shows the vector of the force (P) working on the C stop ring when the pipe is pulled. The component force of (P) is Px and Py, and Px provides the force required to move the C stop ring axis (indicator actuation load). In Figure 8(a), Py > Px, and though the C stop ring is compressed, it is difficult to move it from the groove.

However, Figure 8(b) shows the optimum groove designed for a stable indicator actuation load. When the pipe is pulled to confirm that it is engaged, the indicator actuation load (Px) is expressed as the difference between the C stop ring's sliding resistance (P' x) and the spring force (Sx) described later. In this case, as just mentioned, in order to expose the indicator for the first time when the pipe is pulled to confirm that it is properly inserted, the force P'x must be larger than Sx.

The indicator actuation load satisfies the necessary conditions described above, and thus a delicate balance of angle α and other factors can be maintained.



(a) C Stop ring is difficult to move



(b) C Stop ring is able to be moved

Indicator force $Px = P'x - Sx$

Necessary condition① $Px > Py$

Necessary condition② $P'x > Sx$

Figure 8 Determining the indicator actuation force

The flex-pipe fitting was redesigned to improve the air-tight seal by increasing the initial surface pressure of the packing, but this increased the flex-pipe's insertion and pulling resistance, which made it more difficult to work with. Thus, it was decided that the maximum resistance would have to be under 200N when inserting or pulling on the pipe to make the fittings easy to work with.

In addition, the flex-pipe has some manufacturing variation, and the outer diameter was not consistent. Because the flex-pipe's outer diameter may influence the indicator actuation load, we made bronze prototypes of large-diameter and small-diameter cases to evaluate. The large-diameter pipe represented the largest diameter allowed by regulations, and the small-diameter pipe represented the smallest diameter. Temperature may also be a factor, so tests were conducted at room temperature (23℃), at -5℃, and at 40℃.

Figure 9 shows the results of tests for 20A size pipe. Through much trial and error, we finally were able to maintain the delicate balance at all diameters and temperatures, and with a resistance of under 200N.

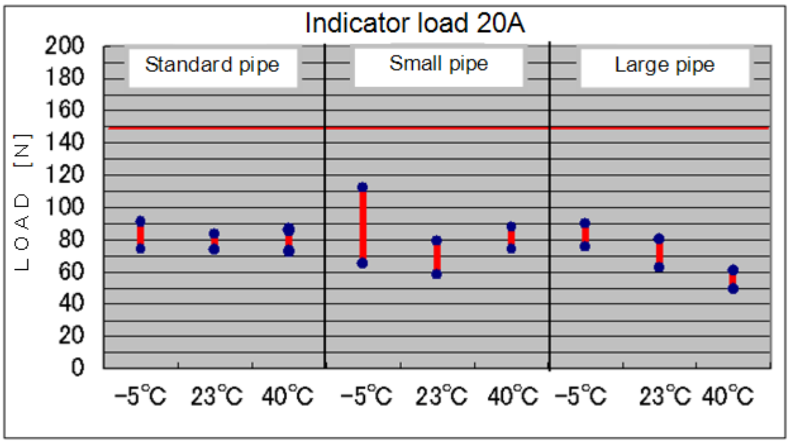


Figure 9 Results for the Indicator actuation load test on 20A pipe

(2) Improving durability with a spring

To improve the long-term air-tight seal on flattened flex-pipes, it was necessary to increase seal surface pressure. However, simply making the packing thicker would have increased the resistance when inserting the pipe, as mentioned earlier, which would make the pipe more difficult to work with. Thus, the idea was to use an internal spring to increase the seal surface pressure. That principle is shown in Figure 10. When the flex-pipe is inserted to its ideal position, the spring latch is moved and the released. This allows the spring to push on the packing, as shown in the enlarged view, and increases the seals surface pressure.

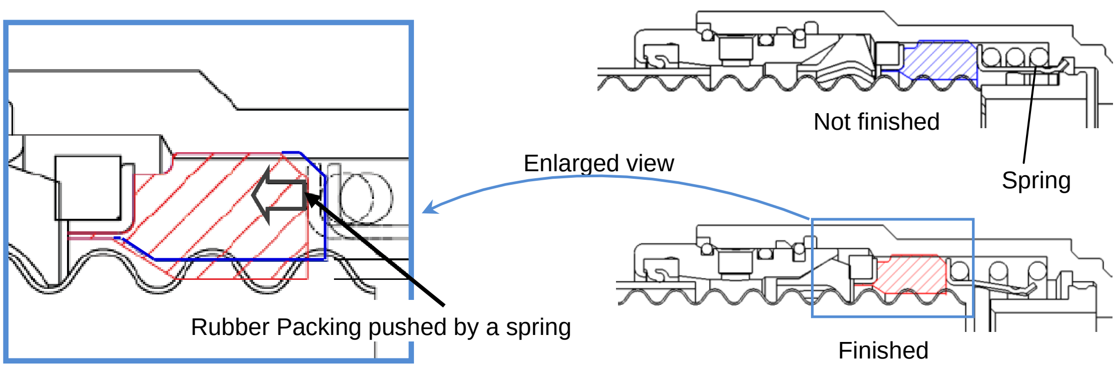
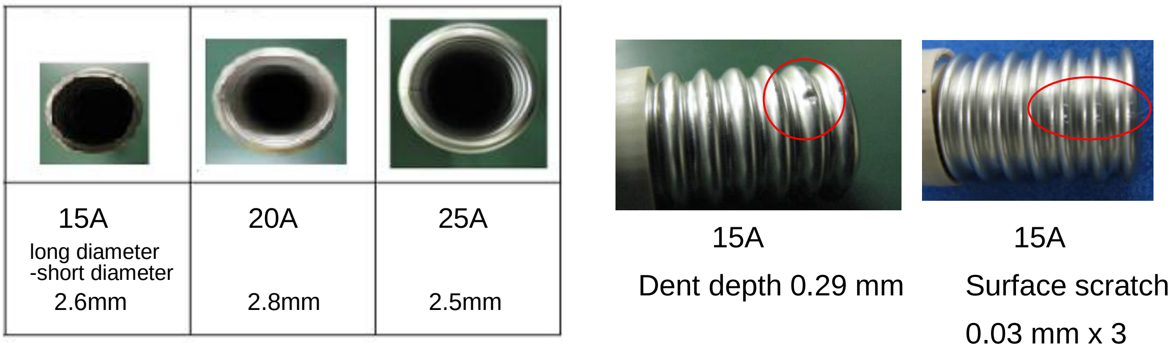


Figure 10 Partial cross section of seal part

To examine the effects of the spring, we conducted durability tests using pipes with various deformations. Figure 11 shows some of the pipes used in the tests. Figure 11(a) shows a pipe that is flattened to the maximum amount that still allows insertion into the fitting. If it were flattened any more, it would not fit inside the fitting, so this represents the most extreme conditions with regards to flattening. The rubber packing is the determining factor in durability, and so we conducted an accelerated test using heat aging. When we conducted the test with packing aged to an equivalent of 50 years by applying 10℃double aging, there was no leaking. We had run a similar test on the previous fitting using a pipe that was deformed to the maximum degree that would still allow insertion into the fitting, there was leaking, so it was possible to significantly increase the range of flattening tolerance.

In addition to flattening, we tested pipes with dents as shown in Figure 11(b), and pipes with external scratching as show in Figure 11(c), and even in these cases we were able to confirm the seal surface pressure of the packing close to the flex-pipe depressions due to the spring force effect, and thus even with the equivalent of 50 years of aging no leaks were detected, confirming the long-term performance of the seal.



(a) deformation (b) dent (c) external surface scratch

Figure 11 Examples of deformed flex-pipes used in testing long-term performance of air-tight seal

(3) Evaluation of general performance

The flex-pipe and its fitting used for gas are manufactured to the specifications issued by the Japan Gas Association(JGA). Table 2 shows an example of the JGA specification evaluation points for a 20A size pipe, and the newly developed fitting meets all these criteria.

Table 2 Example of evaluation points (20A)

Item	Performance criteria	Testing method (critical point)
Air-tight seal	No leaks	Air pressure of 110 kPa x 1 min.
Pressure resistance	No leaks	Water pressure 800 kPa x 30 s
Tension	No leaks	Tension load: 2.7 kN or less
Impact resistance	No leaks	21.0 J of impact
Vibration resistance	No leaks	Vibration range +/- 4mm, 500 rpm, 10,000 vibrations
Stress corrosion resistance	No failure	Ammonia 2 h
Salt water resistance	No corrosion	Salt spray 24 h
Melting resistance	No failure	Creosote oil, others
Gas resistance	No seepage	Iso-octane, 70 h, at 40℃

In addition, we tested fire resistance as an independent item. To prevent the leaking of gas from feeding the flames in the event of a fire, the fitting contains material that will expand when the temperature rises. We applied 800℃ for 30 minutes and measured the volume of leakage, but there was no significant leakage of gas.

(4) Constraints of Installation

Because there are differences between simple testing of materials and actual installation, we devised a piping model to use in installation testing, and using that piping model, we had a installation company monitor the test. In the installation test, a standard piping model and a piping model based on an apartment building pipe shaft (PS) with very tight bends were used because these have the biggest impact on the air-tight seal of the fitting. Figure 12 shows the assembly of the newly developed fitting, while Figure 13 shows a schema of each piping model and installation testing conditions. The workers gave high praise to the new fitting, saying that the new fitting was simpler to work with than the former fitting, and that it was easier to handle.

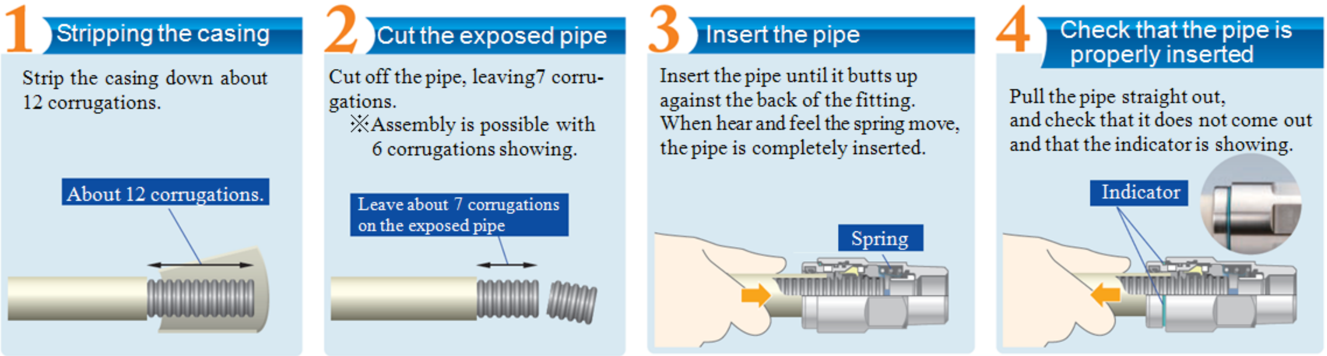
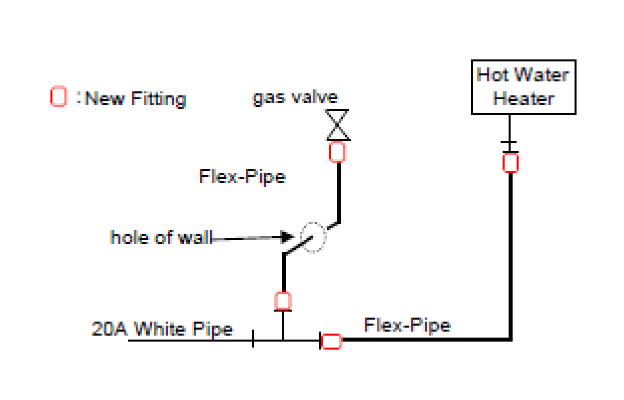
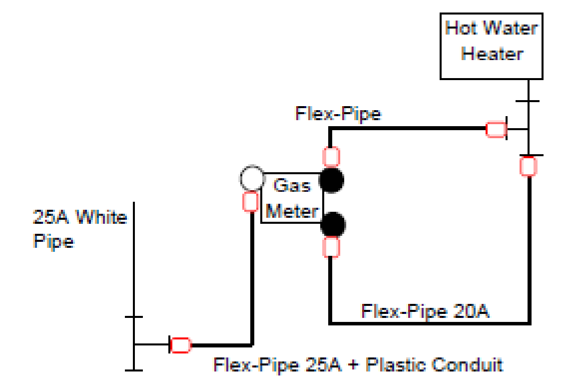


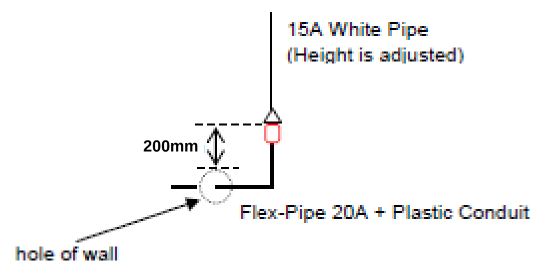
Figure 12 Flex-pipe fitting assembly



Standard piping



Piping which imitated the inside of PS



The conditions which bend that a radius is severe

situation of installation verification

Figure 13 Situation of model piping and installation verification

(5) Other (disassembly)

The indicator can be easily moved with a tool, and by pushing the nut toward the body, the fitting can be disassembled. This structure allows for the fitting to be replaced in the event of a problem with the fitting, leaving the flex-pipe in place, which makes it much easier to maintain.

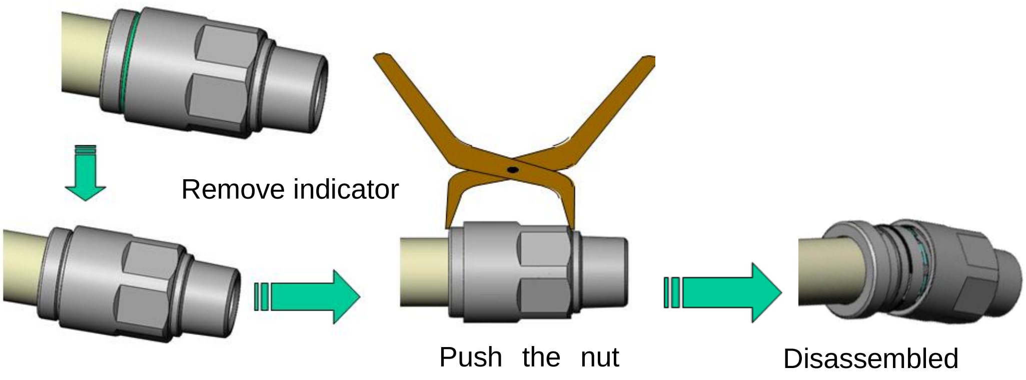


Figure 14 Disassembly of the newly developed flex-pipe fitting

Conclusions

We believe that it is the epoch-making new fitting for the Flex-Pipe with a fail-safe function provided by the indicator and the internal spring to improve its long-term sealing properties, developed jointly by Tokyo Gas Co., Ltd. , Hitachi Metals, Ltd , and Sankoh Co., Ltd.

The new fitting has the following features.

1. When the pipe is inserted into the fitting, a spring is released and the retainer locks the pipe in place. Then, the flex-pipe is pulled to confirm that installation is complete, and an indicator appears to verify. (The indicator fail-safe mechanism ensures that assembly is complete.)
2. When installing the pipe, there is no need for monkey wrenches or other tightening tools, and marking is also not required, making installation easy.
3. After installation, the spring continues to apply pressure to the packing, improving the reliability of seal performance, and reducing the risk of leaks caused by variations in installation.

Tokyo Gas Co., Ltd., has started to adopt this new fitting since April 2010. We believe the Flex-pipe system with the new fittings contribute the improvement of workability and customer’s security.