

# Replacing metal parts with resin for pipe installations, gas equipment

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## **SUMMARY**

The movement to replace metal parts with resin in automobiles and other industrial products is gaining traction. This trend toward resin is spreading to consumer electronics and gas equipment parts. This report will take a look at how resin is beginning to replace metal for gas distribution facilities and gas equipment parts.

Japan's low pressure gas pipelines have transitioned from steel to resin, with polyethylene currently accounting for 40% of all low-pressure underground pipes. A comprehensive polyethylene piping system is beginning to take shape as the resin trend spreads to couplers and valves, in addition to pipes. The switch from metal to resin takes care of the corrosion problem in gas pipes. Furthermore, a polyethylene piping system is more resistant to earthquake damage, resulting in a more stable gas supply.

Resin is also beginning to replace metal for gas equipment parts. At first, the switch took place in pipe parts that carry both hot and cold water. Now brass fittings, headers and steel pipes are being replaced with polyphenylene sulfide (PPS), a leading engineering plastic material. Resin that's used for hot water is exposed to harsh conditions using heat and liquid. Determining whether resin is a suitable replacement for metal would require, first, knowledge of the characteristics of various resin materials, standardized assessments to determine whether those parts are being used in an environment best suited for them, and appropriate testing methods. We conduct water-hammer tests, constant road creep tests and other forms of experiments under water in high-temperature and high-pressure environments on metal parts and their resin counterparts to assess resin's potential as a replacement.

## **KEYWORDS**

Resin, gas distribution facility, gas equipment, metal replacement, lightweight, cost reduction

## **INTRODUCTION**

The movement to replace metal parts with resin in automobiles and other industrial products is gaining traction. Replacing metal parts with resin results in lighter weight and a reduction in costs. It has other benefits: corrosion and earthquake resistance. In automobiles, better fuel efficiency can be expected. In other industrial products, resin has contributed to lower manufacturing and shipping costs. This trend toward resin has spread to consumer electronics and gas equipment parts.

In this report, we will look at how resin is beginning to replace metal for gas distribution facilities and gas equipment parts. In recent years, parts that have been already switched out to resin are now being considered for replacement with even cheaper resin. We will address that in this report as well.

## **SWITCHING GAS DISTRIBUTION FACILITIES TO RESIN**

Diagram 1 shows the West European countries that made changes to their pipe material (1). Around 2000, a majority of pipes were still made of metal. In recent years, that has dropped to about half. Plastic is expected to make up a majority of pipe material in the future.

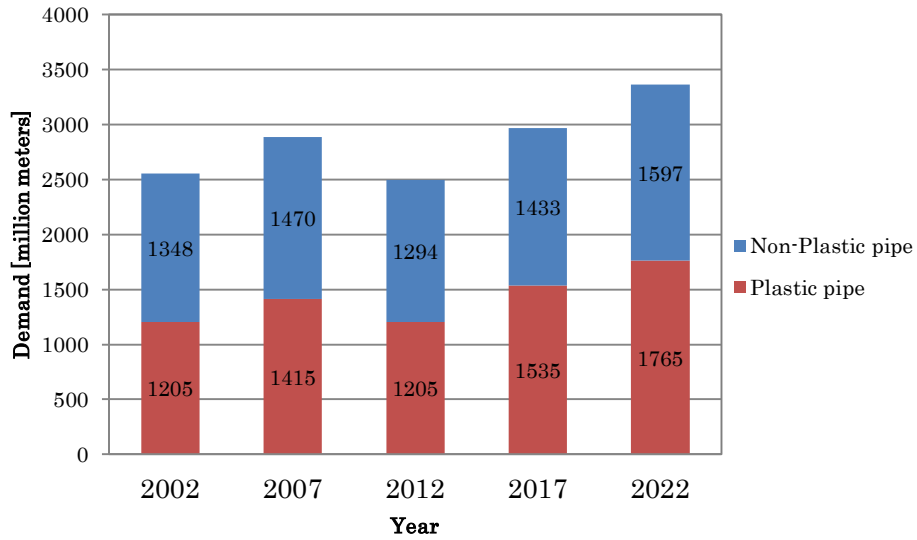


Diagram 1 Changes in Pipe Material in Western Europe

In Japan, low-pressure gas pipelines are being switched from steel to polyethylene. Diagram 2 shows the different types of gas piping. Low-pressure pipes are moving from steel and cast iron, through resin-lined steel, and then to polyethylene.

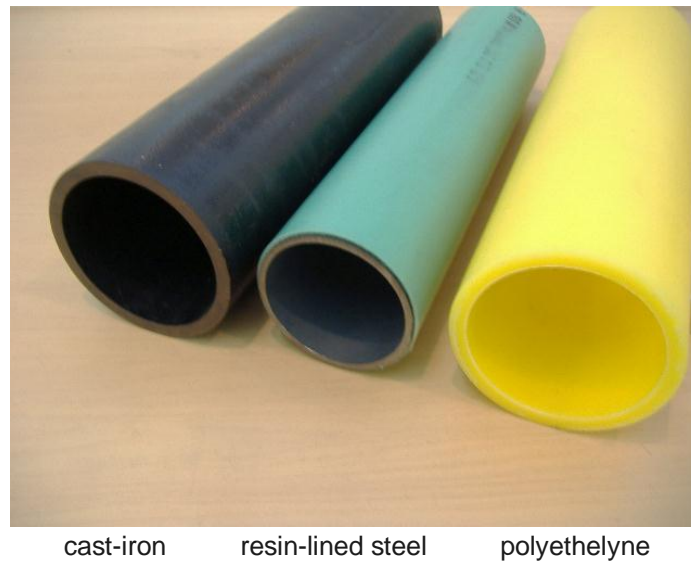


Diagram 2 Changes in Gas Piping in Japan

Diagram 3 shows the switch to polyethylene pipes in Japan (2). Polyethylene pipes are increasing annually. They currently account for 40% of low-pressure underground pipes.

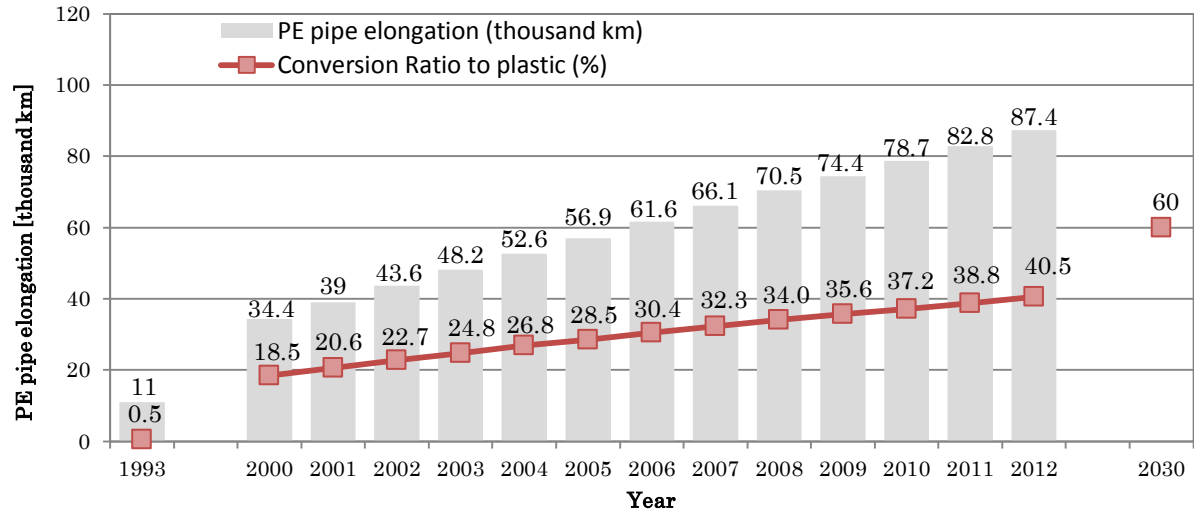


Diagram 3 The Spread of Polyethylene Pipes in Japan

In addition to pipes, resin is spreading to couplers and valves, contributing to a comprehensive polyethylene piping system. One such example is the switch in valve material, shown in diagram 4.



resin metal

Diagram 4 Switch in Gas Valves

The switch to polyethylene from metal takes care of corrosion and earthquake concerns. Consequently, one can say resin contributes to a stable and reliable supply of low-pressure piping. During the 2011 great east Japan earthquake, the polyethylene gas pipes remained undamaged. Japan's goal is to spread polyethylene so that it makes up 60% of all pipes by 2030.

Diagram 5 shows the different types of plastic pipes in Western Europe. PVC, which was the fastest-growing plastic piping material, still dominates the region, but the options are growing (1). In earthquake-prone Japan, polyethylene has been the material of choice over PVC pipe because of its superior flexibility. But Japan can consider options other than polyethylene in the future.

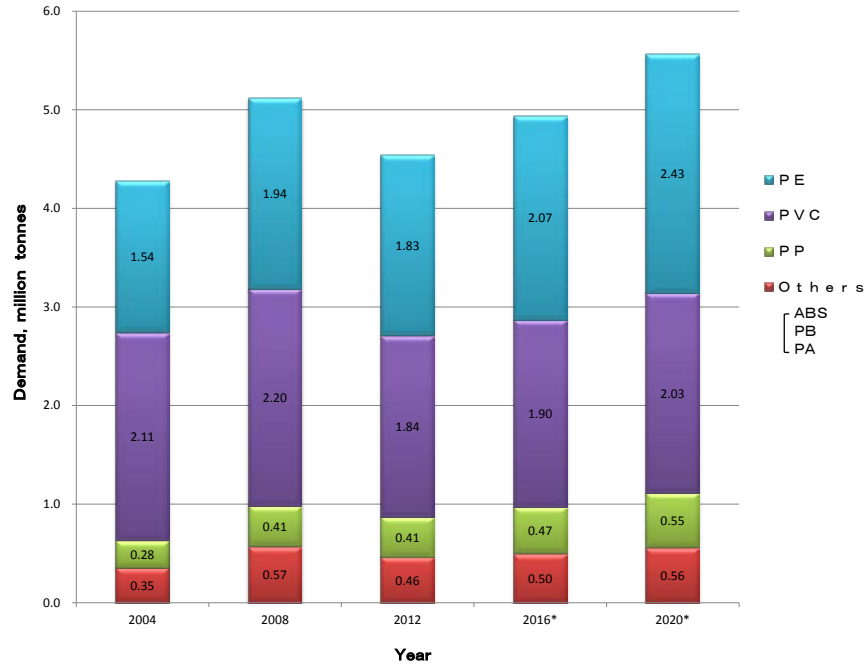


Diagram 5 Different Types of Plastic Pipes in Western Europe

### THE USE OF RESIN IN GAS EQUIPMENT PARTS

Along with gas distribution facilities, gas equipment parts are also being phased out of metal and in to resin. The switch from metal to resin helps reduce the cost of the gas equipment itself and makes the construction work flow easier. The transition to plastic -- in particular, a specific type of plastic with reliable performance in the auto industry -- is taking place with gas equipment parts. With gas equipment parts, the switch to resin happened in piping that carries hot and cold water. Cross-linked polyethylene and polybutene pipes are examples of the plastic pipes. Diagram 6 shows the switch from metal to plastic pipes. Diagram 7 shows the couplers; diagram 8, the headers. Brass couplers and headers are also being replaced with polyphenylene sulfide (PPS), a leading engineering plastic material.



Copper      SUS      rubber      resin

Diagram 6 Changes in Hot-Water Piping



PPS Brass

Diagram 7 Changes in Pipe Fittings



Metal Mixture PPS

Diagram 8 The Switch in Headers

Diagram 9 shows the different classifications of resin. When used as a metal substitute, resin must be especially heat resistant. General-purpose plastic is low cost and is used in everyday goods but is heat-resistant only up to 100 °C. A higher grade of resin is general engineering plastic, which is heat-resistant up to 150 °C. For more heat resistance, there's the super engineering plastic, which withstands heat of above 150 °C. That makes super engineering plastic the best candidate as a metal substitute.

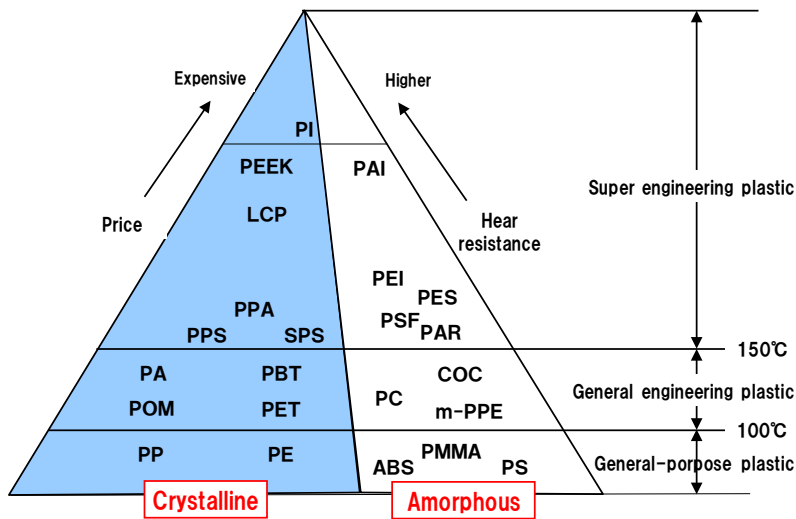


Diagram 9 Classifications of Resin

Restrictions prevent Japan from using resin for flammable parts or parts through which gas emissions pass. Outside of Japan, however, resin is being used for gas equipment. Diagram 10 demonstrates how resin parts are used in hot-water heaters. Fan casings, combustion air guides, emission ducts, emission tops and other such parts are already made from resin. Switching the internal parts of a hot-water heater to resin will create a more reliable product because of its light weight and lower cost. In these areas, Japan has room to consider deregulation.

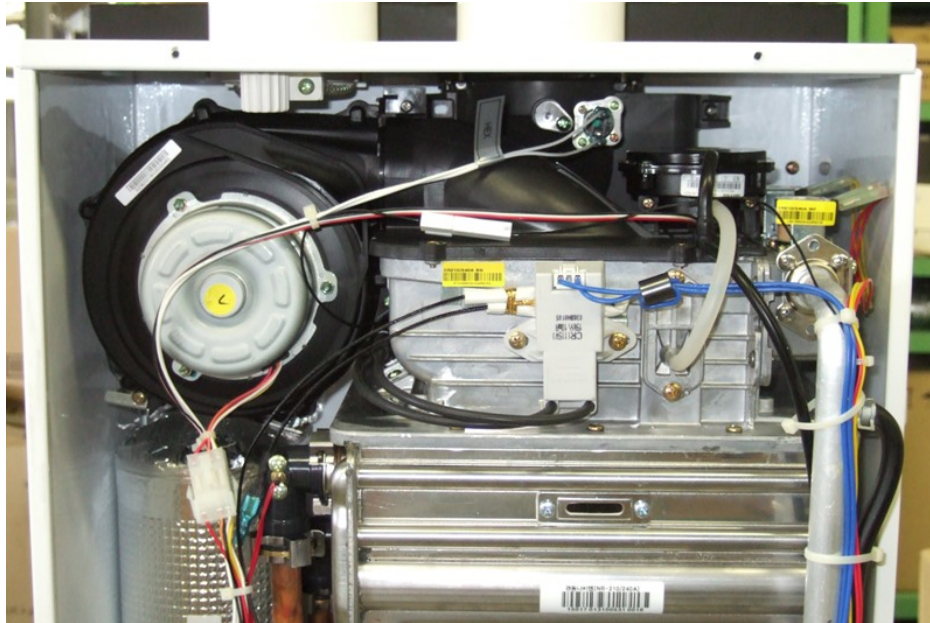


Diagram 10 Example of Resin Used in Foreign Hot-Water Dispensers

**ASSESSING THE CHARACTERISTICS OF RESIN**

The standards used to assess whether resin will be a suitable metal substitute for gas distribution facilities and gas equipment parts vary greatly. Chart 1 compares the different conditions under which gas pipes and hot-water pipes are exposed. Resin used for hot-water pipes are subjected to harsh conditions, such as fluidity and high temperatures. Deciding whether a certain type of resin is suitable requires knowledge of all the properties of that type of resin, proper criteria to determine whether those parts are being used in an environment best suited for them, and appropriate testing methods.

Chart 1 Comparing Conditions: Gas Pipes vs Hot-Water Pipes

	Fluid	Temperature	Environment
Gas pipe	Gas	Low	Mild
Hot-water pipe	Hot water	High	Hard

Diagram 11 details that process. We design and create metal parts and their resin counterparts as the test production, and are conducting destructive tests to see if resin has enough potential as a metal substitute. Failed prototypes undergo stress analysis by finite element method, and are redesigned and correct the metal die until they pass. Then, after a mold is complete, the product is tested. This process gets repeated over and over, until finally, a product passes the criteria.

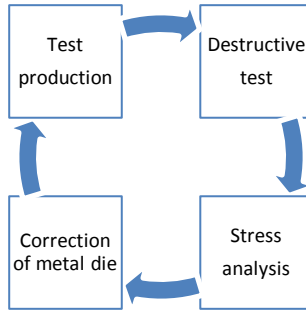


Diagram 11 The Product Development Loop

Throughout this loop, resin manufacturers, mold makers, product testers and analysts necessarily work closely together, exchanging information to create a superior final product. Diagram 12 shows how the four groups work together.

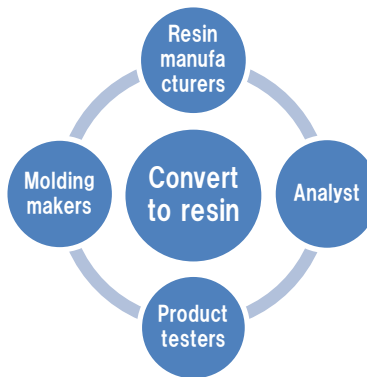


Diagram 12 Working as a Team to Create Resin

The most important factors in product testing and assessment criteria are that they are appropriate for the specific product and the environment in which it will be used. For example, parts that will be used in hot water must undergo a water-hammer test or stress rupture test in high temperature and high pressure, and under running water to determine its viability as a metal substitute.

Furthermore, in recent years, parts that have already undergone a switch to resin are now being considered for yet another switch to cheaper resin. Diagram 13 shows PPS headers fashioned out of a different type of resin. PPS, which is shown in diagram 9, is super engineering plastic. It is a high-performance resin, but also costly. The number of star icons indicates the cost of the resin in diagram 13. We are in the process of determining whether general engineering plastic or general-purpose resin are suitable replacements for PPS. The melting point for PPS is 280 °C, but for general engineering plastic, the melting point is at most 150 °C. The highest specification for Japanese hot-water dispensers is 90 °C with a boiler pressure of 0.3MPa while the water is running. The ability to withstand chlorination levels of 1 ppm is required for sanitation purposes. General engineering plastic can easily satisfy these criteria, but the standards applied to testing PPS against metal cannot be applied to test general engineering plastic as a viable substitute for PPS. That's because under those testing conditions, engineering plastic would melt. New assessment criteria are required.






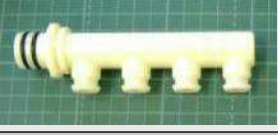



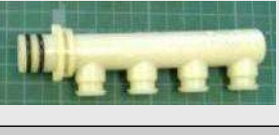

		
PS/SPS ★★★	PS/SPS/LFT ★★★★★	PP/LFT ★★
		
PA66 ★★★	PPS ★★★★★	PP/SFT ★
		
PA/PPA ★★★★★	PA6T ★★★★★	PS/PPE/PA ★★

Diagram 13 Examination of PPS Substitute Resin

Chart 2 shows a list of testing criteria that were considered. Typically, a short-running test and a long-running test that measure endurance take place at the same time for each category. For example, when testing for stress rupture, the short-run test is conducted under low temperatures and low pressure. It is common for longer-running tests to be conducted under higher temperatures and high pressure. However, general engineering plastic has a relatively low melting point, which means it cannot be tested under the same high-temperature conditions as super engineering plastic. Therefore, when testing for stress rupture, the temperatures are lowered and conducted at lower pressure for the long-running test. Short-running tests, which usually are done under low temperature, low pressure conditions, are conducted under low temperatures, but higher pressure. This ended up raising the short-running testing standards for measuring pressure above the long-running testing standards. Raising the temperature during the water-hammer test for general engineering plastic above testing conditions required for super engineering plastic, we set the conditions to assess both water-hammer and long-term heat resistance.

Next, we studied the validity of these standards. Diagram 14 compares the load ratios of super engineering plastic and general engineering plastic in stress rupture and water-hammer test. Load ratio refers to the accumulation of temperature, pressure and time. The total test load for general engineering plastic was set up to surpass that of super engineering plastic. For resin with a low-melting point that complicates high-temperature endurance testing, altering the standards for pressure and time make short-term endurance testing possible by simply maintaining test loads.



Chart 2 Regular Engineering Plastic Assessment Criteria

Test		Metal	Super Engineering Plastic (PPS)	Regular Engineering Plastic
		Heat resistance	> 200°C	< 150°C
Stress rupture	Short-running		150°C, 0.5MPa ⇒ 1000h	130°C, 0.3MPa ⇒ 1000h
	Long-running		130°C, 0.3MPa ⇒ 8760h	110°C, 0.5MPa ⇒ 8760h
Water-hammer			60°C, 2MPa ⇒ 8760h	80°C, 2MPa ⇒ 8760h

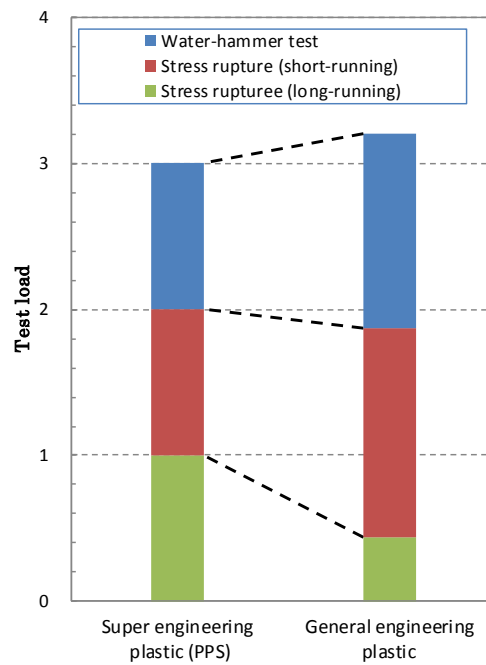


Diagram 14 Comparing Test Loads

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