【Technical Report】

Proposal for factory piping health checks conducted by plastic piping specialists

AVPipingDoctor

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Introduction

The risk of occurrence of accidents leading to environmental pollution or damaging human health caused by deterioration of chemical liquid pipelines is increasing year by year, as more than 40 years have elapsed since Japan's period of rapid economic growth and its factory facilities are now aging. In recent years, secondary disasters caused by pipelines rupturing during earthquakes and fatal accidents where workers have fallen through weakened FRP tanks have also occurred, and preservation and maintenance work is becoming increasingly necessary. Instances have also occurred where construction failures due to new generations of workers or personnel shortages have caused leakage accidents. More reliable construction work and inspection is essential. In order to prevent such accidents ahead of time, it is crucial to gain an appropriate understanding of the condition of factory piping. ASAHI YUKIZAI CORPORATION (AY) has developed advanced non-destructive checking technology capable of checking problems without halting production lines and possesses a proven track record with all kinds of chemical fluid lines (including caustic soda, hydrogen peroxide, nitric acid, hydrochloric acid, and more). These enable us to help support our clients' facility management (with over 1,200 checks completed) through early prediction of risk of accidents and proposals for preventive maintenance. In this report, AY introduces its piping checks for deterioration of polyvinyl chloride pipe (PVC pipe) as an example of the activities of our AVPipingDoctor specialists in forecasting the lifespan of plastic pipelines and planning maintenance policies.

Approaches to maintenance

With regard to maintenance of factory piping, the conventional mainstream approach has been corrective maintenance, in which repairs are conducted after damage occurs. However, in recent years, preventive maintenance (in which maintenance is conducted before damage occurs) is becoming main-stream due to the revision of laws and regulations on environmental conservation, as well as increasing levels of corporate social responsibility.

Since piping for chemical fluids such as acids and alkali liquids involves particular risk of environmental pollution and damage to human health, measures based on preventive maintenance are essential.
Broadly speaking, there are two approaches to preventive maintenance: Time-Based Maintenance (TBM) and Condition-Based Maintenance (CBM). TBM is a method of carrying out maintenance at regular intervals to prevent failures and malfunctions in advance. This method is easier to manage because maintenance is determined according to period of use and frequency of use. However, it has a couple of disadvantages: repairs are undertaken even when failure or deterioration has not occurred, which makes over-maintenance more likely, and there are increased opportunities for initial defects due to unnecessary replacements. On the other hand, the CBM method involves trend management and performing maintenance only on necessary parts when signs of deterioration have been observed, and it enables reduction of maintenance costs because unnecessary replacements can be avoided. However, this method requires suitable checking techniques and accumulation of data.
Most product failures are caused either by initial defects or by aging of parts and products due to long-term use (see Figure 1). AY utilizes newly established non-destructive checking technology and checking results accumulated over many years to perform checks on factory piping at critical times when failure rates are seen to increase. By doing so, we contribute to total cost reduction by achieving Condition-Based Maintenance (CBM), including VE proposals*, by gaining an appropriate understanding of the condition of piping.

*VE proposals: Proposals that include VE (Value Engineering), selection of suitable materials, design, review of construction methods, etc.

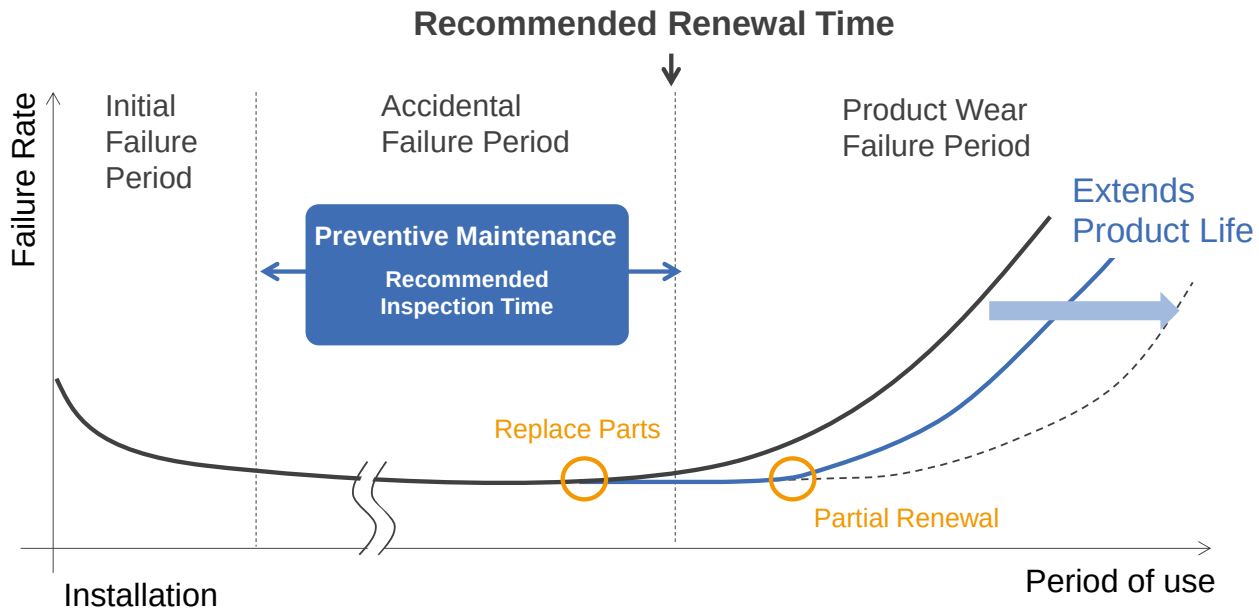

Figure1. Approaches to preventive maintenance (Bathtub Curve)

Deterioration checks for PVC piping

Since PVC piping has excellent corrosion resistance and workability and is lightweight and inexpensive, it is used across a wide variety of fields including water supply and sewerage, agricultural water supply, and factory piping. Due to their high corrosion resistance, the PVC products manufactured by AY have been widely adopted for chemical fluid pipelines in many factories.
Plastic materials generally suffer deterioration phenomena caused by various factors including heat, light, chemicals, and so on. Depending on the conditions of use (fluid, temperature, pressure, etc.) and the environment of use (ultraviolet rays, pipeline stress etc.), PVC piping may also undergo various changes such as discoloration, deformation, cracking, fluid permeation, etc. due to multiple factors. Moreover, in recent years, there have been many occurrences of leakage and fittings disconnecting due to poor construction technique.
To check the deterioration of PVC piping, our approach to checks and proposed countermeasures involve the four steps outlined below (see Figure 2).

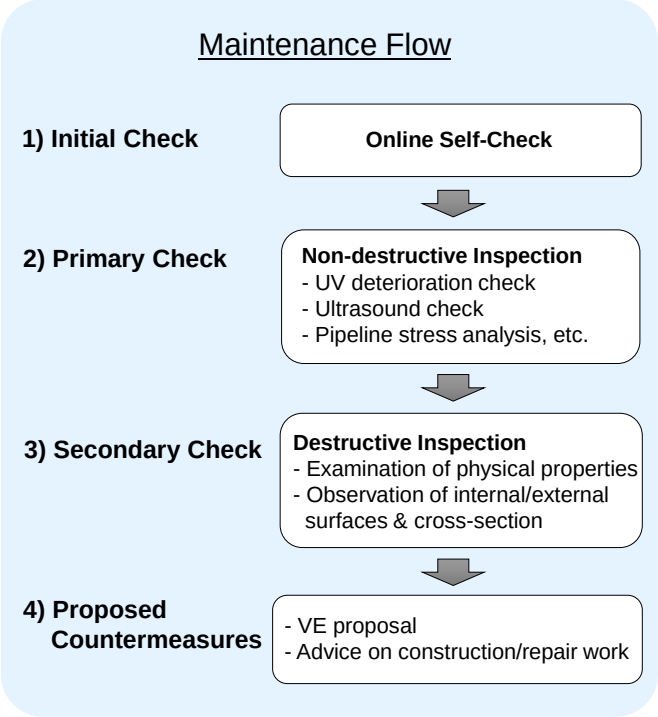

Figure2.Maintenance flow for PVC piping

1) Initial check

If you are not sure where to start in gaining some understanding of the condition of piping that has been in use for a long time, we recommend you perform an online self-check as the first step. This system utilizes big data concerning the relationship between conditions of use and degree of deterioration, derived from many years of checking experience. The service is capable of predicting the approximate extent of deterioration simply by entering the conditions of use of the piping. If you obtain a result indicating that piping deterioration may be a concern, it will be efficient to proceed to the next step.

https://expservice.asahi-yukizai.co.jp/sindan/

Figure3.Online Self-Check

2) Primary check

If the online self-check indicates some cause for concern about deterioration of piping, the most effective second step is non-destructive inspection. Since this is "non-destructive," it does not require halting of your production line, so it can be performed even outside regularly scheduled maintenance times. Non-destructive inspection may include:

(1) UV Deterioration Check using FT-IR
(2) Pipe Wall Thickness Inspection
(3) Fitting Insert Section Inspection
(4) Pipeline stress analysis, and more

(1) UV Deterioration Check using FT-IR

If piping is installed outdoors, the influence of ultraviolet rays on PVC piping is very significant, and over many years of use the surface of PVC piping may change to a white or black color. This indicates that the chemical structure of the PVC is changing, in the process of which the PVC loses its flexibility and becomes hard and brittle. The example below that may lead to halting of production lines and leakage of chemical fluids.

Although this change is only in the extreme superficial layer of the piping, it increases the risk of damage caused by sudden impacts etc., as well as breakages caused by secondary stress due to impact of earthquakes, pipe flexing, water hammering, etc. This can cause accidents, as in the example below that may lead to halting of production lines and leakage of chemical fluids.

<Example of Accident>
UV rays deteriorated the exterior surface of the pipe, lowering its strength, such that when impact was applied to the pipe, it broke.

Material	U-PVC	Temperature	20°C
Nominal size	VP250	Period of use	17 years
Liquid	Water	Installation location	Outdoor

Figure4. Example of destructive accident on PVC piping

In order to investigate the ongoing *progress* of UV deterioration, the most effective method is investigating physical properties via disassembly of piping, but in many cases this cannot readily performed because it requires halting the production line. In such cases, we recommend non-destructive checking service using a FT-IR (Fourier-transform infrared spectroscopy).

In this check method, samples are taken from the extreme surface layer portion of the sun-damaged PVC pipe (see Figure 5), but since the sample thickness is only about 100μm, the check can be performed without adversely affecting pipe strength.

Approx. 2 mm x 10 mm

Figure5. Sampling for UV deterioration

On the basis of the samples collected, we examine changes in additives caused by UV degradation of PVC plastic and measure the amounts of carboxylic acid, hydroxyl group, carboxyl group, polyene structures, and similar chemicals generated by de-hydro-chlorination or oxidation. We estimate physical property retention rates from the accumulated data, regarding correlation between the results of examining physical properties and FT-IR analysis. These estimations are at least 80% consistent with the results of physical property investigation by disassembly of piping, making it possible to predict the ongoing progress of UV deterioration with high probability.

(2) Pipe Wall Thickness Inspection

In PVC piping and composite piping (inner layer: PVC, outer layer: FRP) used for high temperature chlorine liquid pipelines by the soda electrolytic industry as well as slurry fluid, thinning of the internal surfaces of PVC piping may occur.
With regard to changes in the wall thickness of plastic piping, techniques have been established using ultrasonic checking technology to predict remaining lifespan. By using a correction coefficient to correct for the influence of temperature, fluid type, and materials, it is possible to carry out wall thickness inspection with high accuracy.

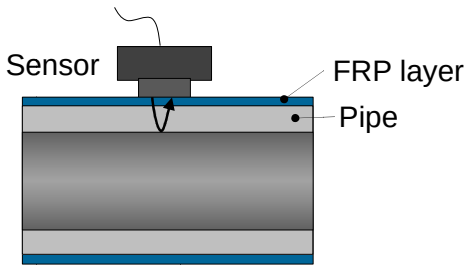

Figure6. Wall thickness inspection using ultrasound

(3) Fitting Insertion Section Inspection

In recent years, many instances have occurred where construction failures due to new generations of workers or personnel shortages have caused leakage accidents (see Figure7). If the insertion margin is shorter than specified, or if the solvent cement is not uniformly applied and thus cannot achieve sufficient adhesive strength, this can easily cause fittings to disconnect or fluids to leak.

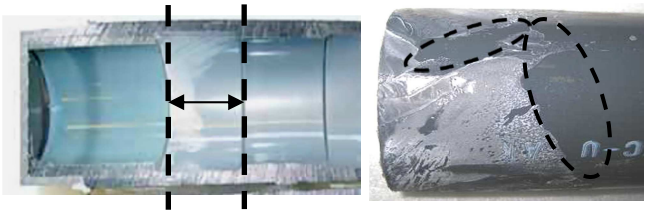

Figure7. Examples of adhesion failure for PVC piping

To inspect for this, we recommend a fitting insertion section inspection using ultrasound or thermo-cameras. The techniques enable us to detect adhesion failure and insufficient insertion margin, making it possible to avoid sudden fitting disconnection and liquid leakage.

(4) Piping stress analysis

In many cases, improper design and piping support causes stress to concentrate in pipelines, leading to breakages. In order to prevent such accidents, we provide services to visualize sections in which stress is concentrated and to recommend appropriate piping construction. From drawings, isometric diagrams, and operational information, we are able to visualize the flexing and warping of piping during operation, concentrations of stress, thermal stress, and similar with pinpoint accuracy, enabling us to gain an understanding of locations likely to suffer damage. Based on the results, we propose safety measures utilizing the design and construction expertise cultivated by our engineering division.
In the absence of drawings or supporting position information, your factory's pipeline data can be easily gathered by 3D scanning devices, enabling us to offer our services based on the drawings thus created.

3) Secondary check

With respect to permeation of chemical fluids, fine cracks on internal surfaces, actual piping strength, and the like, these issues are often difficult to detect using non-destructive diagnosis—thus, it is more effective to utilize destructive inspection to examine physical properties and observe internal and external surfaces. The degree of deterioration is determined based on the degree of decrease in strength (compared to unused pipes), as well as the extent to which permeation of chemical fluids has progressed (see Table1).

Item	Content	Evaluation
External Surface Observation	Observing for discoloration, scratches, etc.	Presence of discoloration, reduced thickness, hairline fractures Discoloration 80% or more: Lifetime of pipeline
Internal Surface Observation	Observing for discoloration, deposited material, etc.	
Pipe Cross-section Observation	Observing depth of discoloration	
Tensile Test (Strength)	Measuring retention of tensile strength	50 to 30%: Review renewal schedule 30% or less*: Lifetime of pipeline *For FRP-clad pipes, 20% or less of the parent pipe
Tensile Test (Elongation)	Measuring retention of tensile elongation	
Impact Strength	Measuring retention of impact strength	

Table1.Criteria for determination of physical properties

4) Proposed countermeasures

Based on the results of the check, we make proposals for construction/repair work and appropriate changes to piping materials, underpinned by our many years of experience in the chemical fluid industry as well as the design and construction expertise cultivated in our engineering division. In addition, where requested we also provide advice on construction and repair of PVC piping, composite piping (PVC+FRP), and PP piping, and we have developed the issuing of licenses (the AY licensing system) ensuring that technicians possess the requisite level of skill in construction techniques.

Fully-fledged operation of the AY licensing system, is scheduled to start in FY2018, but in order to ensure safe use of ASAHI AV products, as the manufacturer we have prepared a maximized backup system. Safety, peace of mind, and high quality construction can be achieved by standardizing piping construction work undertaken by licensed operators.

Valve Life Support

Because plastic valves are not subject to corrosive deterioration like metallic materials are, and because these tend to be thicker than pipes and fittings, in many cases seal sections made of rubber and PTFE will deteriorate and lose valve functionality before deterioration of the main body causes the product to reach the end of its lifespan. Conventionally, when a problem occurs with valve function, the entire valve is replaced each time however, in many cases the valve can continue to be used without further problem simply by replacing the seal section, which is a consumable part. Particularly for large size products and expensive main body materials such as PVDF, it is possible to achieve a total cost reduction by repairing and maintaining an inventory of spare parts.
At AY, we propose reutilizing major parts (such as main valve bodies) by inspecting and repairing products that have been replaced and then discarded in the course of regular maintenance etc. Figure 8 shows an example of valve lifetime support.

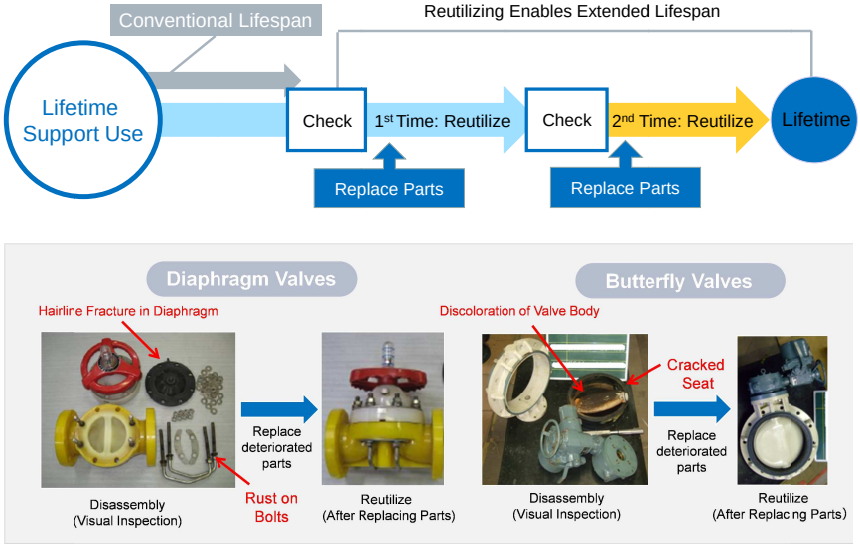

Figure8 .Example of Reutilization via valve lifetime Support

Future Development

If we can gain an understanding of the condition of old piping facilities and take appropriate risk reduction measures, not only can we reduce the risk of major accidents leading to environmental pollution and human health hazards, but we can also extend the life of our equipment and optimize planning for renewal. Moreover, we firmly believe that this can contribute to long-term cost reduction. Aside from this, our checks tracking the progress of deterioration are currently undergoing verification, and we are establishing check techniques for valves and tanks too. We hope that these checking technologies can be used for safe and secure maintenance and management of factory piping, and we remain committed to further efforts to improving this checking technology.