Understanding Chemical Incompatibility

By Michelle Knight

The influence of chemical substances, mechanical stress, and product quality on the performance of a plastic piping system

The identification of a chemical as “incompatible” with a plastic is often misunderstood as a guarantee of the eventual failure of the plastic if it is used in contact with the chemical. Actually, chemicals range in effect from “always causes failure in every circumstance” to “zero effect in any circumstance”. Falling in between these two extremes are most chemicals that might contact the pipe in a typical building installation. In this range, chemicals are capable of having some effect on the plastic, but typically there must be contributions from outside mechanical stresses or some inherent weakness in the plastic part before an actual failure can be initiated.

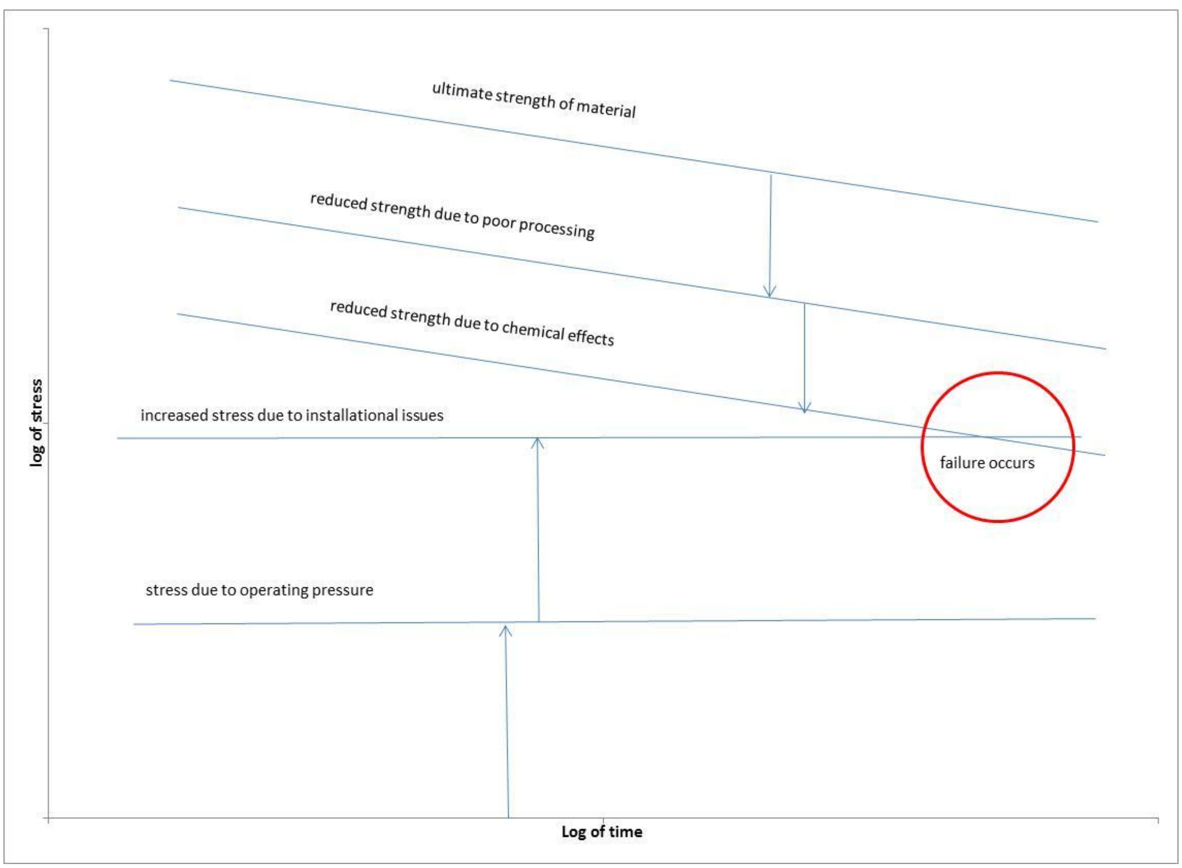
Amorphous polymers like CPVC derive their strength from the fact that they are long chain-like molecules all tangled together. A failure of the plastic occurs when enough chains break or become disentangled that a breach develops in the solid polymer. This breakage and/or disentanglement can be caused by strong mechanical stresses (e.g., impact damage), strong chemical effects (e.g., solvation or plasticization), or frequently some combination of moderate levels of both. Only a relatively small number of chemicals are capable of achieving disentanglement of the polymer chains all by themselves without the assistance of some mechanical or other external force being exerted on the plastic as well. When both chemical effects and external mechanical forces are needed to contribute to overcoming the strength of the material, the mode of failure is known as environmental stress cracking.

The structure of the molecule itself and the quality of part manufacturing both play significant roles as well. If the polymer resin molecule is too stiff or too short, it can be difficult to achieve adequate entanglement during processing. If processing conditions are poor, adequate mixing and entanglement may not be achieved overall in the part to begin with. If conditions are sub-optimal, there may be only certain vulnerable areas of the part (e.g., knitlines or spider lines) where adequate entanglement is not achieved. Lack of adequate molecular entanglement may result in a part that is somewhat lower in strength than it ultimately would be if it were processed under optimal conditions. Other types of defects may result in areas of localized weakness or elevated stress in the part as well. Such defects may include voids, inclusions, or score lines in the part.

Chemicals can disentangle the polymer molecules from each other. As mentioned before, some chemicals are very effective at this disentanglement and require no mechanical stress to separate the polymer molecules from each other. These chemicals are actually solvents or plasticizers for the plastic. Chemicals like tetrahydrofuran (used in solvent cement) and dioctyl phthalate (used in some types of caulks) fall into this category. Other chemicals don’t have any effect on separating the molecules, no matter how much stress there is to help. Water falls into this category. In between, there is a range of chemicals, some of which can help only a little to separate the polymer molecules and therefore require a lot of stress to complete the disentanglement (e.g., ethylene glycol); and others of which are more effective at disentanglement and require only a little added stress to pull the polymer molecules apart (e.g., methanol). Clearly, when lower added stress is needed to cause a failure, the chemical is considered to be more "incompatible".

In an installed piping system the mechanical stresses required to complete the molecular disentanglement process can come from a variety of sources. Besides the operating stress due to the pressure in the pipe, stresses can also come from installation issues such as excessively tight piping hangers, improper connections and joining, inadequate support, impingements, excessive bending, thermal expansion, etc.

When all these factors come together, the strength of the material can be decreased somewhat by quality problems and the effects of chemicals, while the localized stress can be increased by operating pressure and installation issues. When the combined level of stresses in an area exceeds the strength of the material that has been reduced by quality and/or chemical effects, a failure can occur. This is illustrated graphically in the figure below. On the other hand, if mechanical stresses are low, and/or the processing of the material has been sufficient to achieve good molecular entanglement, then the plastic material may perform for a long time with no ill effects, even though it has been used in direct contact with a chemical classified as "incompatible."



Seldom can one completely predict all the mechanical variables and all the different kinds of chemical substances that will end up inside or on the exterior of a piping system. Therefore, it's prudent for the piping system designer and installer to do what they can to control the various factors that can contribute to environmental stress cracking.

First of all, the compound specified should have a reputation for consistently exceeding the minimum strength standards. Lubrizol's family of FlowGuard®, BlazeMaster® and Corzan® products have significantly higher pressure ratings, tensile strength, and/or impact strength than the minimum requirements of the various applicable standards.

Second, the pipe or fittings made from that compound should be sourced from a manufacturer with a reputation for excellence in production quality. For pipe and fittings carrying Lubrizol's FlowGuard, BlazeMaster and Corzan brand name, Lubrizol has chosen to work only with manufacturers with a history of consistent high quality. These manufacturers have also agreed to meet quality requirements above the minimum requirements of the applicable pipe or fitting standard.

Third, the manufacturer's installation instructions should be consulted regarding the best way to design and install the piping system. These guidelines contain recommendations for proper connection and joining techniques, appropriate piping hangers, placement of supports, thermal expansion compensation, etc. Incorporating these recommendations into the design and construction of the piping system can help minimize extra mechanical stress.

Finally, when choosing ancillary products that are intended to be in direct contact with the piping system, such as thread sealants, firestopping materials, pipe insulation, etc., the installer should choose products that have demonstrated little or no effect on the piping material. One should always check with the manufacturer of such products to obtain confirmation that the products can be used with CPVC. For Lubrizol's BlazeMaster, Corzan, and FlowGuard Gold products, Lubrizol maintains a list at www.systemcompatible.com of ancillary products which have been submitted by their manufacturers for testing to evaluate their effects on Lubrizol branded CPVC products and have had their manufacturers agree to other requirements that help assure consistent quality.

The success of a plastic piping system can depend upon the strength of the compound chosen, the quality of the parts produced from it, the stresses imposed from operating conditions and installation issues, and the chemical substances in contact with both the outside and inside of the system. It is worthwhile to consider all these potential influences on performance as the new piping system is designed and installed.

About the Author

Michelle Knight is a scientist in the CPVC research and development department at Lubrizol. She holds degrees in both chemistry and chemical engineering from Purdue University. She has 20 years of experience materials testing and failure analysis of CPVC pipe and fittings used in fire sprinkler, industrial chemical, and potable water distribution applications. Ms. Knight has presented papers on failure analysis of CPVC piping systems at various national organizations for both industrial and fire sprinkler applications.

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