Pipe Systems (public)

PVC pipes in low temperature applications

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Technical Note VX-TN-4P

Introduction

PVC pressure pipes are rated for resistance to internal pressure at 20°C. At temperatures above 20°C the maximum allowable operating pressure must be reduced in proportion to the material strength. Use of PVC pipes in the temperature range from 20°C up to the recommended maximum continuous operating temperature of 60°C is well defined (for more information see Temperature Considerations). However, PVC pipes often operate at lower temperature either in colder climates or in applications involving transport of cold fluids, sometimes well below 0°C. However, in these circumstances, some additional factors should be considered. This technical note discusses some aspects of the use of PVC pipes in low temperature applications. See also http://www.pipa.com.au/docs/PV008.html

Pressure Rating

At temperatures below 20°C, the resistance to internal pressure of a PVC pipe increases as the strength of the PVC material increases. However, it is not customary to utilise this increase in strength by increasing the pressure rating. The nominal pressure rating of the pipe at 20°C, or PN, should still define the maximum allowable operating pressure at lower temperatures.

Chemical Resistance

Most chemical resistance tables are determined by immersion of material samples in the chemical solution of interest at 20°C. There is little data available for lower temperatures. However, susceptibility to chemical attack generally increases with temperature therefore it would be reasonable to apply the 20°C information to lower temperature applications. For more information on chemical resistance of PVC see Chemical performance of PVC. As with all chemical resistance immersion data, it important to note that immersion data is obtained in the absence of any stress and it may be necessary to conduct further testing to determine suitability where the pipe is subjected to a chemical environment while under stress.

Precautions

Impact resistance

The impact resistance of PVC is reduced at lower temperatures. Under impact loading, PVC exhibits a transition between ductile behaviour at room temperature and brittle behaviour as the temperature is reduced. The ductile to brittle transition temperature is dependent on formulation. For some grades, impact strength at -20°C is approximately half that at +20°C [1]. Other references give state that impact strength of pipe grades at -1°C is 70-90% of the 23°C value. [2]

The addition of impact modifiers, such as those used in PVC-M pipes, improves the impact resistance of PVC and can shift the ductile to brittle transition to lower temperatures. Similarly oriented PVC pipes, PVC-O demonstrate enhanced impact resistance. Nonetheless, when using PVC pipes at low temperatures, care should be taken that installed pipes are protected from impact damage.

Provision for Expansion and Contraction

Consideration must also be given to thermal expansion and contraction in situations where the installation temperature differs from the operation temperature, or where thermal variation is likely during operation and maintenance. The coefficient of thermal expansion is 7×10^{-5}/ °C which means that for example, a pipe installed at 20°C and cooled to -10°C during operation, will contract by 2.1mm for every metre length.
In particular, layouts should ensure that thermal movement does not impose significant bending moment at rigid

connections or to bend and tees. See the Vinidex Water supply Manual and AS/NZS 2032 - Installation of PVC pipe systems, for guidance on provision for thermal movement.

Temperature Changes

Any temperature changes in a system should be gradual to minimise the risk of "thermal shock". A large temperature gradient or a rapidly developed temperature gradient across a pipe or fitting wall can lead to internal stress in the wall [3]. The magnitude of the stress can be calculated by the following formula
s = Ee = 0.5αΔTE

where
s = Stress (MPa)
E = Modulus (MPa)
e = Strain
α = Coefficient of thermal expansion and contraction (/°C)
ΔT = Change in temperature across the wall

So if cold contents, say at -10°C are rapidly introduced into pipeline at 20°C, the stress in the pipe wall would be:

$s = 0.5 \times 7 \times 10^{-5} \times 30 \times 3200 = 3.4$ MPa

Where the inside wall is colder than the outside, the inside of the pipe experiences a tensile stress. This is in additive to other stresses in the system such as residual stress, bending stress (perhaps due to restrained thermal movement) and hoop stress due to internal pressure. Stresses can be magnified in fittings, particularly those with complex geometry such as bends and tees. Past experience of problems in low temperature fluid transport applications, has invariably been in fittings and although not conclusively proven, are thought to have resulted from this type of sudden temperature gradient across the wall. Many apparently identical systems continue to perform satisfactorily.

1 Engineering Design with polyvinyl chloride, Technical Service Note W121, Second edition, Vinyls Group, ICI, 1980
2 Handbook of PVC Pipe, Unibell PVC Pipe Association
3 Plastics Pipes for Water Supply and Sewage Disposal, Lars-Eric Janson, 4th Edition, Borealis, 2003