COST BENEFITS AND LONG TERM BEHAVIOUR OF A NEW ALL PLASTIC PIPING SYSTEM

J. Korsman, S. de Boer, I.M. Smits[1]

[1] Department of Mechanical and Process Engineering,
Nuon N.V., Duiven, Netherlands

INTRODUCTION

The predominant piping system in the District Heating (DH) industry over the last century consists of a steel medium pipe, polyurethane (PU) insulation and a polyethylene (PE) outer casing (abbreviated to St/PU/PE). This system performs very well. However, steel may rust and the insulation properties of PU may suffer under the influence of water. Therefore, joints have to be made with care and require a certain level of workmanship.

From this perspective, an all plastic piping system might have some distinctive advantages. Plastics do not corrode (that is, a lot slower than steel). Some plastics are extremely flexible and allow for transportation on reels for rather large diameters, thus reducing the number of joints (figure 1). Some plastics may even be welded.

Fig.1. plastic piping in long lengths on reels

This paper describes the summary of the report on “Cost benefits and long term behaviour of a new all plastic piping system” [1], subject of the IEA Implemental Agreement on DH&C Annex VIII. This report focuses on an all plastic piping system, with polybutylene medium pipe, PE foam insulation and an outer casing made of PE (abbreviated to PB/PE/PE systems). Because this is a new piping system, different aspects of the application of this system compared to conventional piping systems are investigated.

LIFE CYCLE ASSESSMENT

Life cycle assessment of the different piping systems shows the impact of several life cycle stages on the environment. One clear conclusion is the dominance of heat loss on the environmental impact [2]. The contribution of heat loss can be subtracted from the long utilisation period of district heating systems. The life time of a pre-insulated pipe, which is about fifty years, is very long. Increasing the utilisation period of the district heating system only enlarges the contribution of heat loss on the environmental impact.

Enhancing the products performance (e.g. increasing insulation thickness) leads to a lower environmental impact. Increasing insulation thickness can not be done endlessly because there is an optimum between insulation thickness extension (decreasing heat loss) and surface extension (increasing heat loss). For economic reasons the optimum for increasing insulation thickness may be around ten percent of the actual insulation thickness. The production phase will consequently rise in impact contribution, but since the effect of production on the total impact is less than one percent, this increase is acceptable from an energetically point of view.

COST BENEFIT ANALYSIS

For both high and low density district networks, costs for materials and installation of the PB/PE/PE system are comparable to conventional St/PU/PE networks [2]. The use of twin pipes only decreases the investment costs due to smaller trenches and lower network lengths. Also, twin pipes (in theory) have lower heat loss which leads to lower costs over its lifetime.

Costs for piping length is the most determining factor in total costs for plastic pipe networks.

Installation costs for the plastic pipe system are uncertain, because experience with the system is still very limited. Costs for installation of the PB/PE/PE system therefore can be seen as a maximum, that will decrease as contractors become more experienced with the system.

Fig.2. Installation of plastic pipes still requires some experience

LONG TERM BEHAVIOUR

Three studies have been conducted on the long term behaviour of the new all plastic piping system. The first study concerns an assessment of the thermal insulation by polyethylene foam. The second study presents the quantification of the change in the thermal insulation of the PE foam as a function of the exchange of gas or vapour between foam cells and the environment. The third study describes the risks for corrosion due to oxygen diffusion through plastic piping systems for the total system, heat exchangers, radiators and couplings.

The fraction of open cells was determined experimentally. The final result of these experiments is that the fraction of open cells is not exceeding 6 ± 3 %. The temperature gradient, heat loss and the water flux were calculated for several situations.

The main conclusion of this study by TNO Science and Industry is that insulation properties of PE foam deteriorate significantly when wet, even though the material itself seems to remains intact, whereas PU may degrade. So in order to reach optimum performance, the system needs to be dry. Because water vapour can diffuse through the PB pipe and PE foam, water condensation can occur in the foam cells. This, however, is a very slow process that takes 30 years in the worst case before all foam cells are filled with water.

Fig.3. Example of welding the PB pipes

Calculations to quantify the ageing of foam insulated pipes for district heating are also performed by TNO Science and Industry. The foams studied are PE (polyethylene) foam in the PB/PE/PE system and rigid PU (polyurethane) foam in the steel pipe system.

The initial value for the heat conductivity of the PU foam in the St/PU/PE system is similar to the PE foam of the PB/PE/PE system. The characteristic ageing time is longer for the steel pipe system as a result of the larger medium pipe and casing thickness, which forms a larger barrier for oxygen and nitrogen.

It is expected that the ageing rate of PE and PU foam will be almost identical if both foams are insulated by the same plastic casing. The permeation behaviour of the casing and medium pipe for blowing agent, oxygen and nitrogen is decisive for the ageing rate.

A major threat to heating systems is the diffusion of oxygen through plastic materials. As a consequence there is a risk for corrosion in the steel and copper components of the total system, e.g. heat exchangers, radiators and couplings. To overcome the diffusion of oxygen through the PB medium pipe, the PB/PE/PE system is supplied with an EVOH coating. This is a diffusion barrier that reduces the ingress of oxygen. Nevertheless there is still a certain amount of diffusion of oxygen, even with the EVOH barrier.

The wall thickness decrease over time of steel components is acceptable in case of an equally distributed corrosion attack, but oxygen may initiate localised corrosion, for instance pitting corrosion. At the joints of the PB tubes with the carbon steel tubes the oxygen levels are at the max and this oxygen will react instantaneously with the carbon steel. The corrosion also takes place at locations with a thin protective layer and with conditions that foster corrosion. The risk of severe localised corrosion (pitting) in the carbon steel parts under the mentioned conditions is not quantitatively predictable. But if pitting occurs, it is an out of control process and corrosion rates of mm/year are possible.

A key issue is to maintain an optimal water quality and prevent ingress of air and salts because the occurrence of pitting corrosion is strongly promoted by the presence of salts, especially chlorine.

HEAT LOSS ANALYSIS

With the study on ageing of the insulation foams and heat loss formulae, the heat loss of both plastic and steel systems are determined and compared. Also measurements are performed to provide an experimental foundation [3].

The current PB/PE/PE system contains an air gap between the medium pipe and insulation foam, causing higher heat loss results than theoretically predicted (figure 4). An effective insulation thickness is therefore calculated, resulting in an effectiveness of the insulation foam of 84% with regard to the expected insulation performance.

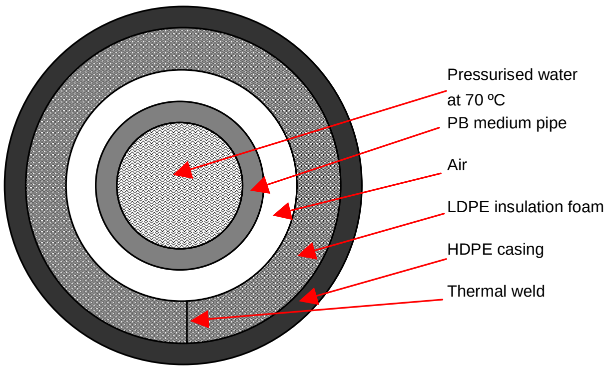

Fig.4. The PB/PE/PE system is not bonded and contains an air gap between medium pipe and insulation

The geometry of the plastic PB/PE/PE piping system could be optimised by closing the gap between service pipe and insulation foam. Further, heat loss could be decreased by increasing insulation of the piping system. A larger outer casing for each diameter for PB/PE/PE would result in lower lifetime heat loss than St/PU/PE systems series 1 and comparable heat loss to series 2.

SYSTEM OPTIMISATION

The new flexible PB/PE/PE piping system in its standard configuration is not insulated as effectively as conventional rigid St/PU/PE (Series I) piping. This is mainly due to less insulation thickness and relatively fast degassing of the PE foam. The obvious method to reduce heat loss is to increase insulation thickness. This would lead to comparable heat loss values.

Calculated heat losses for the distribution system are in the range of 240 to 290 W per house, or 20 – 25% of the yearly consumption [4].

An alternative to reduce heat loss is to install a separate pipe for domestic hot water distribution, thus creating a three pipe system (figure 5). This allows for lower average temperatures in supply and return.

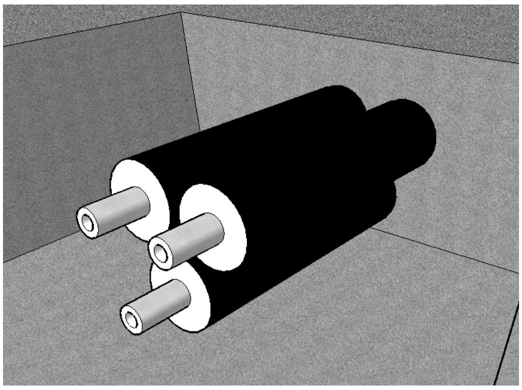

Fig.5. Example of optimising the laying practice of plastic pipes

During warm periods, two of the tree pipes can be shut down completely, as no space heating is required. In our calculation, this was done for 730 h/year.

If the network is designed to heat up quickly, this shut down period may be extended significantly, thus further reducing heat loss.

NOMENCLATURE

DH	District heating
PB	Polybutylene
PE	Polyethylene
St	Steel (St37)
PU	Polyurethane
PB/PE/PE	Polybutylene pre-insulated DH system
St/PU/PE	Steel pre-insulated DH system

LITERATURE

[1] Korsman, J., Boer, S. de, Smits, I. (2008): “Cost benefits and long term behaviour of a new all plastic piping system”. IEA Implemental Agreement on DH&C Annex VIII 2008.

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