

# Advanced energy transmission fluids for District Heating and Cooling (1996 N2)

## Introduction

The application of drag reducing additives in district heating networks is a promising technology to improve the competition conditions of those systems. The pressure loss and therefore, the pumping costs of existing networks can be reduced or their capacity can be increased. The pipes and fittings of new planned networks can be designed in smaller diameters. Other possibility to use the drag reducing effect are the decrease of the supply temperature due to an increasing mass flow while keeping the capacity constant or the integration of further (far away) heat sources which becomes only economic due to decreasing pumping costs. Resources can be saved and the pollution of the environment can be reduced.

During the last 13 years, lots of investigations concerning the application of cationic surfactants as drag reducing additives have been carried out in Canada, Denmark, Finland, Germany, Korea, The Netherlands, Sweden and the United States. Experiments with different kinds of cationic surfactants such as Ethoquate, Habon(-G), Obon(-G), Dobon(-G), C<sub>16</sub>TASal etc. have been carried out. The effects on pressure drop behaviour in straight pipes, helical tubes as well as the heat transfer behaviour in those geometries have been investigated. The heat transfer of shell and tube, helical tube and plate heat exchangers has been examined. Furthermore, heat meters, fittings, pumps, the corrosion behaviour, environmental aspects and water hammering have been investigated when using drag reducing surfactants.

In laboratory tests and full scale investigations in Denmark, Germany and the Netherlands, the general suitability of cationic surfactants - especially of Habon-G and Dobon-G in combination with Sodumsalicylate - as drag reducing substances for district heating systems could be proven. Based on those results, strategies to apply surfactants in real district heating systems have been developed.

Several important projects have been supported of the IEA. Important subjects such as environmental aspects, the influence in a large scale plate heat exchanger, corrosion behaviour etc. have been investigated within the bounds of projects supported by the IEA.

Under IEA Annex IV, four projects concerning the field of research "Advanced Transmission Fluids for District Heating and Cooling", have been supported. Several institutes and companies of different countries have been carried out theoretical and experimental work. Some of this work has been planned and carried out in cooperation with various partners.

The first project (project A) is dealing with the simulation of the behaviour of comprehensive transport networks with special consideration of heat exchangers which separate the transport system from the distribution network.

Simulation results for the application of surfactants in a real system are given. Within the context of project A, economic calculations have been carried out. These calculations consider general models and give an overview of the savings in costs which can be expected under certain conditions.

In the second project the influence of drag reducing additives in small domestic heat exchangers and on flow meters which are installed in small consumer stations has been determined. Four different kinds of heat exchangers and four different flow meters have been investigated.

Aim of project C was the collecting of data and information about commercially available drag reducing surfactants and of regulations of different countries concerning the approval of drag reducing additives in district heating systems. Therefore, a questionnaire has been developed, which was handed to all members of the Experts Group "Advanced Transmission Fluids for District Heating and Cooling" to register the state of conditions of the different IEA member countries.

When using drag reducing additives inside

pipes, the heat transfer from the fluid on the inner pipe area is reduced significantly. Therefore, the last project has been carried out in which the improvement of the heat transmission conditions in tube bundle heat exchangers by installing turbulence increasing obstacles inside the pipes was investigated.

#### **A. Modelling of the Location and Requirements for Heat Exchangers in District Heating Networks using Friction Reduction Additives**

In the context of this study, a simulation program for calculating the behaviour of district heating systems operating with drag reducing additives has been developed. The behaviour of district heating transport systems as well as of single components - especially typical heat exchangers such as plate, shell and tube and helical tube heat exchangers - can be calculated with the program "TenSim", when applying drag reducing additives.

The simulation program can be used to modify existing networks and create new district heating systems to realize the operation with surfactant solutions. Single system parts (existing and additional necessary devices) - especially heat exchangers - can be designed or modified to achieve a design which guaranties a well working operating mode.

By simulating several cases of modified systems and comparing the results of the simulations, an optimum technical solution can be achieved.

In an example calculation the simulation program has been tested. The test system (the system Völklingen Luisenthal) has also been used for a long term full scale test (application of Dobon-G/Sodiumsalicylate), so that all technical data (data for apparatus like pumps, heat exchangers, pipes, geographical data etc.) were available as well as results for the operation with drag reducing additives. Therefore, simulation results could be compared with results of a real application. The comparison showed that the simulation

results calculated with "TenSim" reproduce the real results sufficiently.

A necessary condition for the application of drag reducing additives is the economic viability. Comparing the modified system working with drag reducing surfactants (that means the optimum technical solution which has been found with the simulation tool) and the original system, operating with pure water, it is possible to estimate the savings in cost due to the application of surfactants.

Therefore, cost functions have to be evaluated in further studies to be able to calculate the investigations that are caused by the additives. Those functions for German conditions have been developed in several studies carried out at the University of Dortmund.

Furthermore, economics calculations have been carried out. In this studies, a general model has been used to estimate the potential in saving costs on principle.

Next step concerning the application of drag reducing additives in district heating systems should be the simulation of concrete transport systems with "TenSim" - including the modifications. Furthermore, economics calculations (estimations) should be carried out for real systems to get the necessary informations about the economic aspects of the application of drag reducing additives in existing district heating networks.

#### **B. Experiments on the Effects of Friction Reduction Additives on Substances**

This report discusses the results a NOVEM-supervised investigation aimed at assessing in how far the surfactant Habon-G can reduce friction losses in domestic water supply systems utilizing heat from district heating systems. Earlier work has shown that Habon-G, when added to heat transport systems, has a beneficial effect on the required pump capacity. Habon-G produces a laminar flow, and this reduces not only the friction losses in pipelines but also the heat transfer.

This report discusses the effect of Habon-G on

both parameters as observed in four different heat exchangers and heat flow meters used for domestic water supply systems.

For the purposes of the present investigation a test facility was made in which the district heating circuit is simulated by a closed loop which included an adjustable electric heater. The domestic water circuit was connected to a high-capacity water supply booster. The heat exchangers and heat flow meters were integrated in the facility and could be inserted one at a time into either circuit by means of ball valves.

Measurements made on the heat exchangers indicate that all four heat exchangers meet the specified requirements, although there are some differences. The flow in them still seems to be turbulent, despite the laminising effect of Habon-G.

The heat flow meters do not all meet the requirements. Two were found to be at error and their inaccuracy increased with increasing Habon-G concentrations. The percentage errors of the other two meters were below the threshold and were not affected by the presence of Habon-G.

As observed earlier, adding Habon-G to the water in district heating systems has a beneficial effect on the flow resistance and reduces the heat losses in the feed lines. The present investigation shows that addition of Habon-G does not affect the heat transfer in the domestic water supply system in any material way. However, a critical assessment of the type of heat flow meter to be used is called for.

### **C. Survey of Environmental Restrictions to the Use of Additives in District Heating and Cooling Systems**

Aim of this project is the collecting of data and information about commercially available drag reducing surfactants and of regulations of different countries concerning the approval of drag reducing additives in district heating systems.

Bruun & Sørensen has created a questionnaire, which was handed to all members of the Expert Group to register the state of conditions of the different IEA member countries.

The project was started at the beginning of October 1994. The questionnaire was answered from nearly all member countries (Canada, Denmark, Finland, Germany, Korea, Sweden, The Netherlands and USA). B& S has analysed the answers and summarized the information. An unambiguous conclusion covering the situation in all countries cannot be drawn. In most countries there are no concrete rules related to this new technology.

It seems to be clear that a certain reluctance towards the introduction of new additives in general is a common attitude. The technology has not been declined in any of the countries.

The activities on this field are finished. The final report of project C, "Survey of environmental Restrictions to the Use of Additives in District Heating and Cooling Systems" was closed in May 1995 and is available.

### **D. Improving of Heat Transmission Properties of Tube Bundle Heat Exchangers by Installing Obstacles inside the Pipes**

In this study the heat transfer and pressure drop of drag reducing surfactant solutions inside straight pipes with obstacles has been investigated. Therefore, an existing test rig, mainly consisting of two closed loops (one for cooling and one for heating), has been modified. As cationic surfactant, Habon-G (hexadecyldimethylpolyoxethylammonium cation and 3-hydroxy-2-naphthoate as counterion) has been applied.

Spiral springs of different pitches have been used as obstacles to increase turbulence and therefore, the heat transfer which is significantly decreasing when applying drag reducing additives (up to 95 %). The springs

consist of wire made of stainless steel of a diameter of 1 mm. The diameter of the spring has been a little bit higher than the inner diameter of the pipe to guarantee a certain support.

For pure water the installation of the obstacles leads to an increase in heat transfer of nearly 100 % in maximum. The behaviour is dependent on the pitch. The characteristic for the 8 mm and the 16 mm springs are almost identical while the Nusselt numbers of the 24 mm spring are smaller.

For surfactant solutions the heat transfer behaviour strongly depends on concentration, temperature and pitch. For 500 wppm the improvement in heat transfer is only small. The conditions of the origin state (water without obstacles) - which is the requirement for a sufficient operation with surfactants - cannot be reached with this concentration.

The Nusselt characteristic is parallel below that one for water without springs.

In contrast to the 500 wppm solution, the 125 wppm and 250 wppm show a completely different behaviour. At low Reynolds numbers the characteristics start in the range of that one for water without obstacles and rise - at a certain Reynolds number - up to the values for water with obstacles. This critical value is dependent on concentration, temperature and pitch of the spring. With increasing pitch the critical point is moving to higher Reynolds numbers as well as with increasing concentration. With increasing temperature, the critical values also move to higher flow velocities until a certain temperature, which is dependent on concentration, is reached. Behind this point, the values are moving to lower Reynolds numbers and the characteristic is moving to higher Nusselt numbers because the

drag reducing effect is weakening.

For a concentration of 250 wppm, the heat transfer conditions of the origin state can be reached with the 8 mm spring above Reynolds = 25,000 and with the 16 mm spring above 56,000. For 125 wppm, the conditions of the origin state can be reached with all investigated springs (for the 24 mm spring, the condition  $Re > 47,000$  has to be fulfilled).

Therefore, the aim to reach the heat transfer coefficients of pure water without obstacles could be reached under certain conditions.

On the other hand, measurements of the pressure drop showed a significant increase. This increase is - compared to the increase in heat transfer - superproportional.

The strongest increase could be observed for the 8 mm spring for 250 wppm. In this case the pressure drop is increasing of about 850 %.

The characteristic course of the drag characteristic mainly shows the same dependencies as the Nusselt characteristics.

The most important influence has the pitch of the spring. Comparing the 8 mm and the 24 mm spring for a 250 wppm surfactant solution, the pressure drop increase of the 8 mm spring is 850 % in maximum compared to 200 % in maximum for 24 mm.

Considering the technical application and assuming that the heat transfer has to be at least as large as for water without obstacles, an enormous pressure drop increase has to be spent. Thus, for the technical application, detailed calculations of the changed conditions of the complete system have to be carried out in order to check the installation of spiral springs inside pipes as a measure to improve the behaviour of tube bundle heat exchangers when using drag reducing additives.