International Energy Agency

IEA District Heating and Cooling

Programme of Research, Development and Demonstration on District Heating and Cooling

New Ways of Installing District Heating Pipes

Published by

Novem
Netherlands agency for energy and the environment

Acting as operating agent for the IEA District Heating and Cooling project

1999: T3.2

International Energy Agency

Program of Research, Development and Demonstration on District Heating

New Ways of Installing District Heating Pipes

Dr.-Ing. Frieder Schmitt

Dipl.-Ing. Heinz-Werner Hoffmann

MVV Energie AG

Luisenring 49

D-68142 Mannheim

Preface and Acknowledgements

The International Energy Agency (IEA) was established in 1974 in order to strengthen the co-operation between member countries. As an element of the International Energy Program, the participating countries undertake cooperative actions in energy research, development and demonstration.

District Heating is seen by the IEA as a means by which countries may reduce their dependence on oil. It involves the increased use of indigenous or abundant fuels, the utilization of waste energy and improved energy efficiency. With the same objectives District Cooling is getting a growing interest. The positive environmental effects of improved energy efficiency will give an additional and very strong impulse to raise the activities on District Heating and Cooling.

IEA's Program of Research, Development and Demonstration on District Heating was established in 1983. In the period between November 1983 and March 1997 under the auspices of the IEA 4 programs were carried out, Annexes I to IV.

In May 1996 Annex V has been started up. The following countries co-operate in Annex V: Canada, Denmark, Finland, Germany, Korea, the Netherlands, Norway, United Kingdom and Sweden. The Executive Committee has set following priorities:

- Optimization of operating temperatures
- Balancing the production and demand in CHP
- Cost effective DH&C networks
- Fatigue analysis of district heating systems
- District heating and cooling in future buildings
- Handbook about plastic pipe systems for district heating
- Optimal operation, operational availability and maintenance in DH systems

NOVEM is acting as the Operating Agent for Annex V.

General information about the IEA District Heating and Cooling Program will be given by:

IEA Secretariat Mr. Mel Klimann 9 Rue de la Federation F-75775 Paris, Cedex 15 FRANCE +33-1-405 767 85 Fax: +33-1-405 767 85 E-mail: 'kliman@iea.org'	The Operating Agent NOVEM Mr. Frank van Bussel P.O. Box 15 NL-6130 AA SITTARD The Netherlands +31-46-4202332 Fax: +31-46-4528260 E-mail: 'nlnovfvb@ ibmmail.com'

This report is part of the project "Cost effective DH&C networks" with the tasks

- cold installation of rigid district heating pipes
- new ways of installing district heating pipes
- reuse of excavated materials

The work on the task new ways of installing district heating pipes has been monitored by the "IEA-Experts Group Cost Effective Networks" (EG) with Dr.-Ing. Frieder Schmitt from "MVV Mannheimer Versorgungs- und Verkehrsgesellschaft Energie AG (MVV Energie AG)", D-Mannheim, as project leader and chairman of the experts group.

The members of the Experts Group have been:

- Sten Tore Bakken, Norway
- Gert Boxem, The Netherlands
- Nigel Garrod, Great Britain
- Heinz-Werner Hoffmann, Germany
- Manfred Klöpsch, Germany
- Ture Nordenswan, Sweden
- Per Rimmen, Denmark
- Kurt Risager, Denmark
- Veili-Pekka Sirola, Finland

The chairman wants to thank everybody who has contributed and made it possible to carry through this work - especially every individual of the EG for making a good effort and showing a positive will to cooperate. A special thank to Mr. Sirola and Mr. Kivistö for their special contributions of material from Finland. Mr. Kivistö, EKONO ENERGY, Espoo – Finland was subcontractor on this project and dealt on the task twinpipes. This contribution entitled 'New Ways of Laying Pipes – Savings and Benefits Achievable with Twin Pipe' is attached to this report. Thanks also to the manufacturers who made some material available to us.

Content

1 Summary

The highest potential for cost-reductions of district heating networks lies in the earthworks. By using advanced pipe-laying technologies the trench's cross-sectional area may be shrunk considerably. In contrast to the conventional Side-by-Side laying of pipes the earth masses and costs can be lowered significantly by putting the two pipes on top of each other or using only one plastic jacket for the supply and return pipes as is the case with the Twin-Pipe system.

The Piggy-Back laying requires a narrower trench which has to be excavated a little deeper than with conventional Side-by-Side laying. The pipeline is designed using standard equipment specified by EN 253.

The Twin-Pipe system is used up to a medium pipe diameter of DN 150. It also requires a narrower trench. In addition, the Twin-Pipe features improved thermal insulation and requires only half the number of pipe-runs when compared to conventional DH-pipe systems.

The new laying technologies show some cost advantages versus the standard methods within the considered diameter range of less than DN 150. The cost benefit is about 10 to 20 %. The Piggy-Back laying is cheaper even with pipe diameters of DN 200 and larger.

The cost-advantages of the new laying alternatives have been calculated for conditions that apply in Germany and Finland. This means high resp. low civil costs on the one hand and construction with vertical resp. sloped trench-walls on the other hand.

The German conditions roughly result in equal costs for Piggy-Back or Twin-Pipe systems. Here, the overall costs for both techniques are about 85 % of those of standard laying. When combined with the well established cold installation technique the costs can be further reduced to about 70-75%.

In Finland, the situation is more in favor of the Twin-Pipe system (81%) over the Piggy-Back laying with its 92% of the reference costs. Taking the benefits of the improved insulation into consideration costs for the Twin-system would reduce to 71% of the reference.

2 Introduction

The invest into new district heating networks in Central and Northern Europe is estimated to be about half a Billion US$ per year. With new laying technologies it seems to be possible to reduce the overall costs by 10 to 15%. The prospected savings of 50 to 75 Mill. US$ explain the utilities' interest in these developments.

The installation of preinsulated plastic jacket pipes is widely standardized, see CEN standards [1,2,3,4] as well as the manufactures' guidelines for design [5]. The pipelines are built from prefabricated material and laid Side-by-Side inside the trench according to well approved techniques. Common practice is to divide the building costs into three blocks

civil costs
material costs
installation costs.

The material costs can only be influenced a small degree by further rationalization of the production. For increased cost-effectiveness the civil-work block seems to be worthwhile to consider, since civil costs make about 50% of the overall costs and they still account for about 30% in Northern Europe where these costs are traditionally known to be low.

Two ways of construction have been established which primarily reduce the volume of earthworks for the pipelines and also influence their installation. One of these techniques arranges the pipes not horizontally (Side-by-Side) but vertically on top of each other (Piggy-Back laying), whereas the other combines two medium pipes in one jacket pipe (Twin-Pipe). Piggy-Back Laying has been practiced for 7 years while Twin-Pipes are in use for 15 years. Both techniques allow smaller trenches and thus lower the required efforts for civil-work.

In this report the technical specialties of the two techniques are described and possible savings are demonstrated.

3 Description of the Systems

In addition to the before stated literature [1 to 5] the common laying technology for plastic jacket pipes is described in the construction regulations of the national DH-associations, for instance [6, 10]. The Piggy-Back laying and the Twin-Pipe system are yet mentioned only occasionally and their international recognition is not yet on the same level as for the standard laying technology.

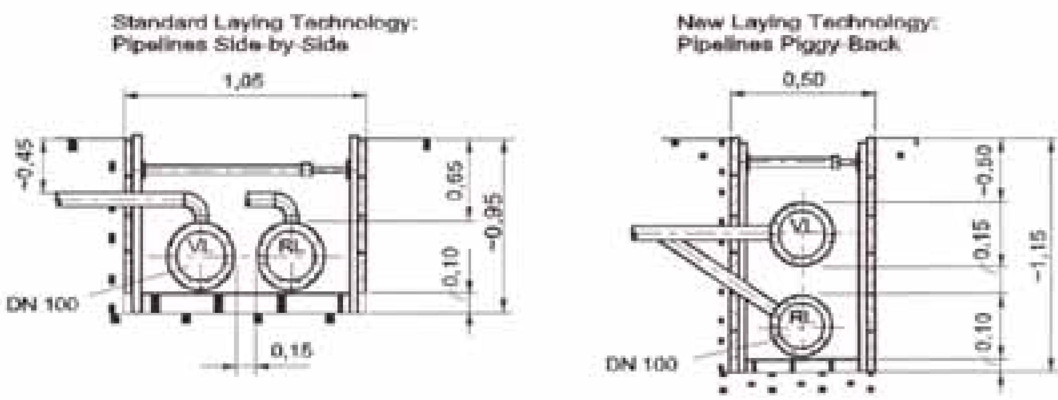
In the following the two new techniques are described in comparison to the horizontal arrangement of pipes. The Piggy-Back laying is possible for all pipe diameters. The technique yet has been applied up to pipe-diameters of DN 400. Twin-Pipes are only made for small pipe diameters up to about DN 150 (upper limit DN 200).

Quick construction usually results in reduced costs while the benefits are rather hard to quantify. The more efficient utilization of the applied machines and materials is evident.

Vertically arranged pipes often require less change of route for the crossing of existing lines. A practical example is given in Figure 3.2. In the case of horizontal arrangement of pipes the electric cable would have been moved to a different location. Through vertical arrangement of pipes the shifting of the cable could be avoided. Needless to mention that vertically arranged pipes can be twisted so that afterwards they are horizontal which may be advantageous in another given situation. Surely, the optimum case is if one is flexible to change pipe arrangement upon needs.

3.1 Piggy-Back Laying

Fig. 3-1: Trench dimension for nominal pipe diameter DN 100

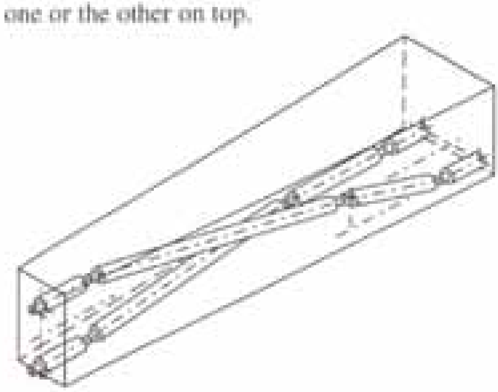


If one arranges the supply and return pipes on top of each other the trench will become narrower and deeper than with standard laying. The reductions in trench volume depend on pipe diameter. As a rule of thumb may be used. The trench width reduces about 40-50% in comparison to the standard technique. Accordingly, the masses for excavation and back-filling are reduced by about 35%. These relations are shown in Figure 3-1.

In the case of smaller pipes the trench support can usually be omitted if the trench is left open for a short period of time. The soil has to remain stable for the time of open trench (e.g. one day), such that the letter doesn't collapse even under the vibrations of the passing traffic, refer to chapter 5. By means of appropriate construction site organization often times the trench bracing may be avoided completely.

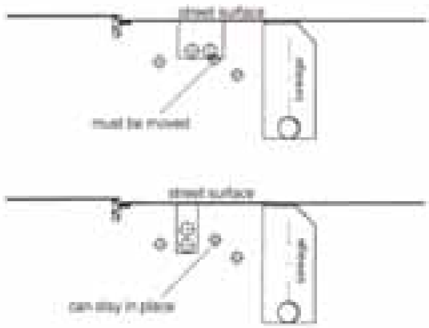
The question of how pipes are laid, whether the return or the supply pipe is on top, can not be answered in general. Depending on the particular situation it may be advantageous to put one or the other on top.

Fig. 3-1b (right): Transition from Side-by-Side Laying to Piggy-Back Laying



If the pipe is prewarmed the supply pipe should be put on top since the top-pipe is easier to reach than the bottom one.

Fig. 3-2: Example of avoiding the need to move existing buried lines through Piggy-Back Laying



If the pipes are cold installed economical reasoning suggests an arrangement where the supply pipe is the bottom one. The pipe then has a higher coverage which, in turn, raises friction and reduces the necessary efforts for compensation.

Up to now supply-pipes were generally put on top while obeying the experience that leakage usually occurs at the supply pipe which can then be repaired with less effort. In order to reduce the efforts for compensation one interconnects both pipes - which becomes more and more common practice - and then both pipes are exposed to the same expansions and limited stresses (anchor bridges, refer to IEA-report on "Cold Installation of Rigid District Heating Pipes"[8]). Because of this supply and return pipe might eventually show the same statistical occurrence of leakage.

An additional reason that suggests to put the supply-pipe to the bottom arises from the later operation of the network. When the pipe is under compressive stress it is less prone to buckling or instability the deeper it is laid into the soil. Moreover, heat losses are reduced when the warmer supply pipe is put deeper into the ground. Generally, the decision where to put the supply and where the return pipes has to be made during the planning phase carefully balancing the before mentioned arguments. For information on the special advantages of Piggy-Back Laying the reader may refer to Table 3-5.

3.2 Twin-Pipe

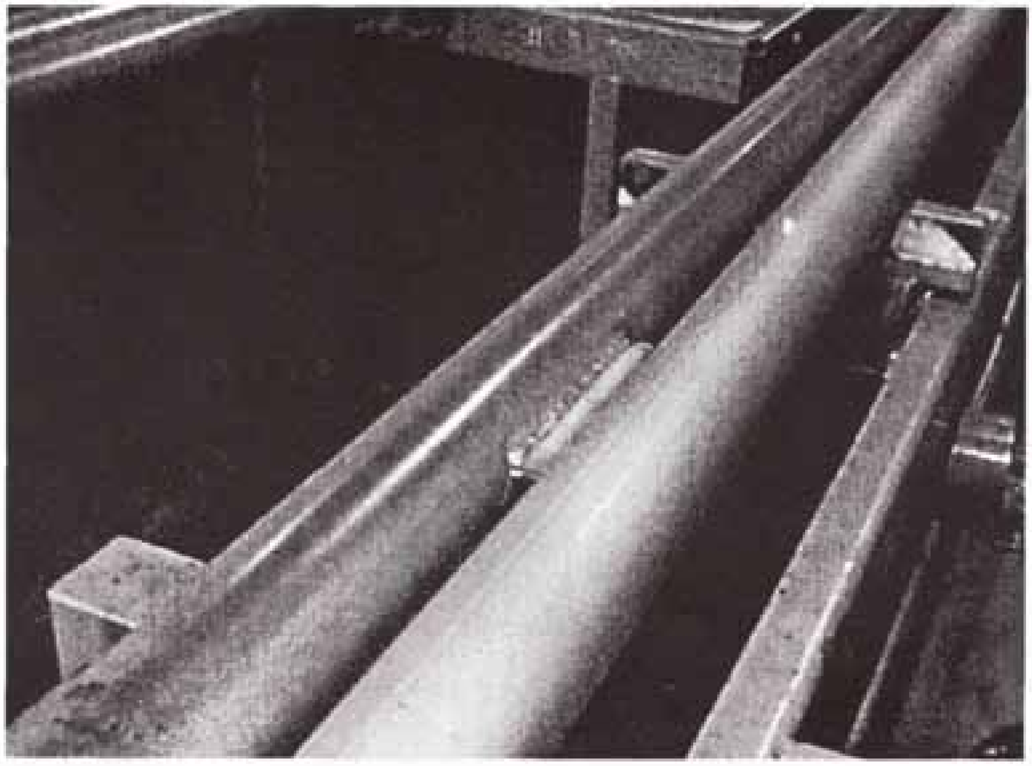
The Twin-Pipe is a Scandinavian development aiming to build cheaper networks in the small diameter range (The manufacturers offer Twin-Pipes up to a diameter of DN 200 in their catalogues). The invention is claimed to be of Swedish origin since a patent had been filed there on March 3rd 1977. Reports from Finland mention the first systems of such kind in the year 1984. Today, the European market is primarily served by two Finnish and two Swedish manufacturers. In Finland Twin-Pipes have already reached a remarkable market share in the small range of diameters.

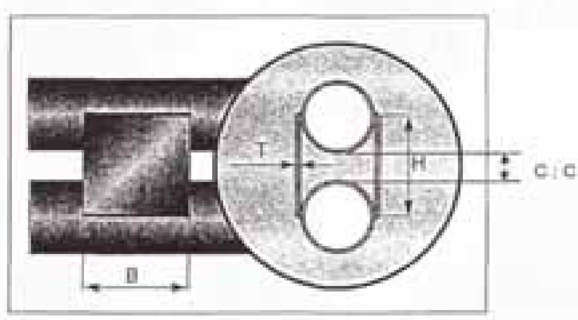
Of the pipes DN 20 to DN 80 Twin-Pipes have a share of 30% of all installed pipes (more detailed information on this may be drawn from Annex II, page 4.) In Germany, there is only a small number of companies using twin pipes so far, but their number seems to be on the rise.

The pipe material to the most part complies with the specifications given in EN 253, however, the twin-pipe itself is not yet included in this norm. In Finland, the system is covered by the Finish DH-association's specifications where the critical dimensional tolerances are defined. The products of the different manufacturers do not show any remarkable differences. There are some differences in the spacing between medium pipes when comparing Finish with Swedish Twin-Pipes. The largest inequalities exist in the way the two pipes are fixed to each other. On the necessity and the shape of the fixtures one gets divergent answers from he manufactures. For the transmission of forces fins of different shape are welded between supply- and return pipe. This is done during pipe production or on the construction site. Additionally, plastic spacers are used to guaranty the position-tolerances of the pipes. In this point constant changes were made during the past.

From the perspective of pipe statics the fixing of medium pipes via the PUR-foam shall be sufficient. Simply with prefabricated parts such as bends, tees, service connections etc. a sufficient metal fixture shall be always necessary. For these, mainly two shapes of fixture are known so far, see . 3-3, as are either a short and rigid fin between the pipes or a sheet metal that is welded onto the pipes from either side.

Fig. 3-3: Two kinds of pipe fixture
Top: Type 1 – ABB-Ecotwin, Finland
Bottom: Type 2 – Aquatec-Ecotwin, Germany





The manufacturers do not require these fixtures for straight pipe runs. Obviously, production criteria are ruling this decision. For pipes larger than DN 100 fixtures are used in order to be able to meet the required tolerances. For small pipes oftentimes plastic spacers are used which don't have any static function. Furthermore, it is reported that in some cases fixtures were removed on the construction site after welding the pipe-runs together.

Besides static relevance the fixtures are of concern since they impose unwanted heat bridges between the supply and the return pipe. This effect will be treated in chapter 6.

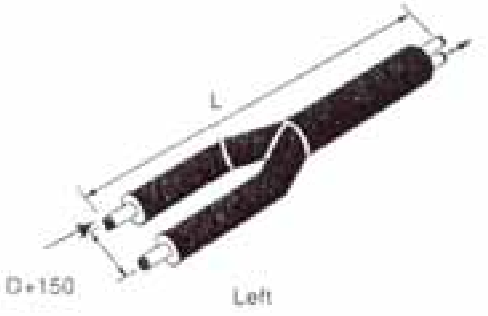
The major advantages of Twin-Pipes as opposed to conventional laying, besides their reduced civil costs, are the simplification of installation and the greater freedom for pipe routing, according to Table 3-5.

When compared to single pipes concerning compensation the properties of Twin-Pipes may be expressed as follows:

In Finland Twin-Pipes and single pipes are always preheated when the straight section exceeds twice the friction length. This enables to lay the pipes without expansion cushions but requires to keep the trench open for a long period of time.

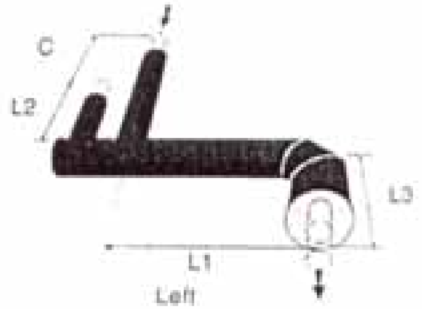
In other occasions one uses Twin-Pipes (Berlin) because they may be cold-installed, too. Because of cold-installation, again, expansion cushions were used (even though supply and return pipe are rigidly connected by fixtures).

Fig. 3-4: Custom parts of the Twin system



While single pipes only allow for small angles of misalignment of about 3°* at pipe joints Twin-Pipes offer more freedom (*In Finland, 5° are allowed for a preheated system). Arbitrary angles of misalignment can be done in the horizontal plane without the need for special precautions. For Twin-Pipes no restrictions apply for diameters up to DN 125, even without preheating.

3.3 Specific Advantages of the Piggy-Back Laying and the Twin System



Since many influences have to be accounted for when evaluating the laying technology, the properties of the different system have been listed in the following table for the sake of clarity. Also, the advantages of both systems are compared.

Table 3-5: Advantages of the new laying technologies

Piggy-Back Laying	Twin-Pipe
+ low volume of excavation / backfill, short construction time, limited construction space	+ low volume of excavation / backfill, short construction time, limited construction space
+ lateral branch	+ lateral branch, equal coverage of branch and main pipe
+ least-cost branch applicable	+ small cross section of trench and, consequently, a reduced need to move existing underground lines
+ small cross section of trench and, consequently, a reduced need to move existing underground lines	+ easy installation in a shallow trench
+ deeper pipe needs less compensation	+ half the number of muffs
+ applicable for pipe sizes > DN 200	+ arbitrary angles of misalignment of straight pipe runs
+ standard parts according to EN 253, equipment is well established	+ favorable thermal insulation (see chapter 6)
+ high degree of flexibility to route around buried obstacles	+ high degree of flexibility for routing
+ cold installation possible without restriction	+ cold installation possible without restriction
+ single-day construction possible if pipes are cold-installed	+ single-day construction possible if pipes are cold-installed

The program of Twin-Pipes offers a variety of custom parts. As an example some valves are shown in Fig. 5-3. In addition to that Fig. 3-4 illustrates the switching joints from Twin- to single pipe systems.

4 Compensation

The thermal prestressing is an important measure of compensation and, therefore, influences the installation of pipes considerably. Bearing this in mind it should be checked whether preheating shall be applied for either of the new techniques.

Piggy-Back Laying

Vertically installed pipes can be each independently designed according to the recognized regulations, e. g. [7]. The bottom pipe has an increased coverage and experiences higher friction forces. This reduces the reaming displacements at the open pipe ends.

In principal, Piggy-Back pipes can be laid with or without preheating. The remaining displacements can be preferentially be handled by expansion cushions, which have to be designed accordingly [7]. The issues, which have to be obeyed when laying without preheating, are discussed in greater length in the report on "Cold Installation of Rigid District Heating Pipes" [8].

Twin-Pipes

In Finland, Twin-Pipes are always installed with preheating when the straight section is longer than twice the friction length. Preheated lines can be installed without measures for compensation.

Preheating has to be considered when calculating the overall construction-time and costs.

If one aims to reduce construction time, e. g. single-day construction, it is possible to backfill Twin-Pipes right after their installation. In this case, they will be 'cold installed'. The expansions resulting from cold installation can be handled in approved fashion by means of expansion cushions, especially when the displacements are moderate due to the rigid connection of supply and return pipe by fixtures.

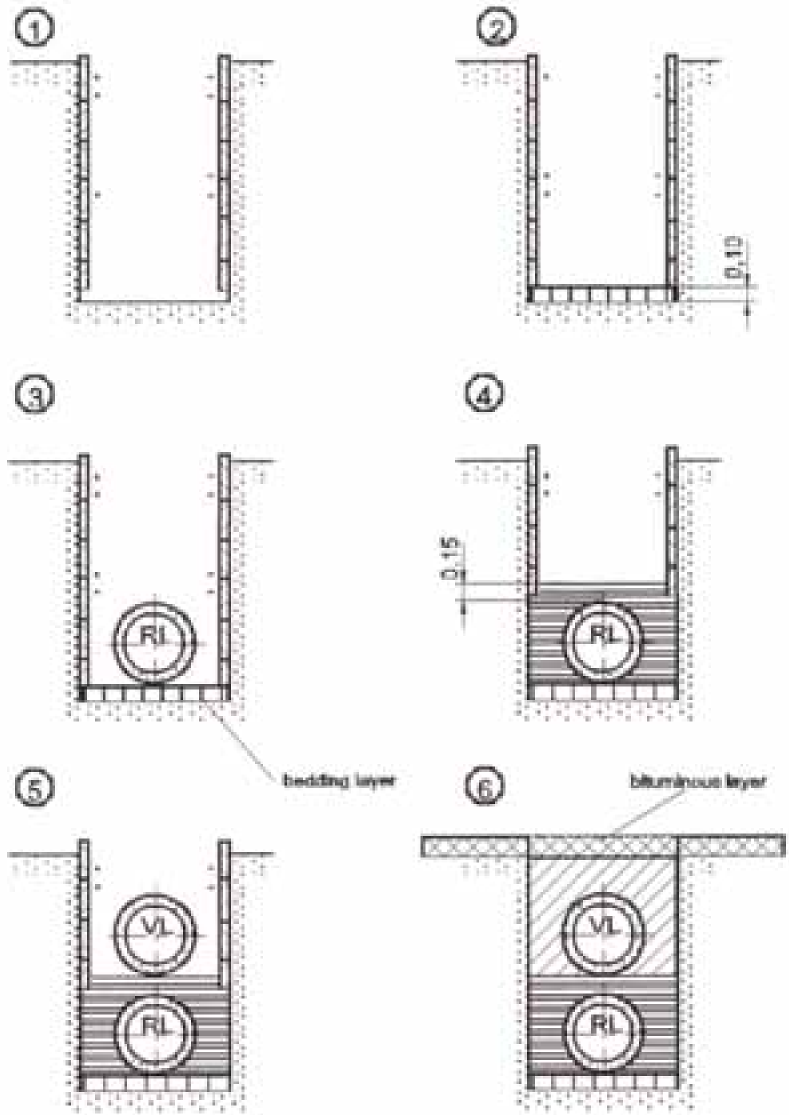
The fixtures between the pipes should introduce the stresses into the pipe such that no increased wall thickness is necessary.

In the early 90^{th} there was a development in Finland aiming to overcome not only the above described compensation but also preheating. One did preheat the supply pipe already during manufacturing and welded it onto the cold return pipe. After that, the pipes were inserted into the jacket and the whole set-up filled with foam. Although the problems of pipe deformation seemed to be in acceptable limits not just during production but still at the construction site, this type of pipe has not gained a great market-share. It was just applied occasionally where further details may be learned from Annex II, page 7.

5 Construction

When comparing pipeline construction in Northern and in Central Europe, it becomes evident, that in Northern countries pipe trenches are built with sloped walls even in street areas while in Central Europe these are done with vertical walls. Just in grass-areas sloped trenches are used. Vertical trench walls need almost always support when left open over a longer period of time.

Fig. 5-1: The burial of vertically arranged DH-pipes



The different trench shape must be taken into consideration especially for the comparison of civil costs. Vertical trenches may become necessary due to heavy traffic or limited space next to the trenches. But they may also be justified by economic reasons when high specific cost for civil work shift the cost optimum towards small volume of excavation. In Scandinavia the costs for civil-work are lower than in Central Europe thus making sloped trenches more cost-effective in majority of cases.

In any situation the costly bracing of the trench should be avoided. If the trench is less than 1.25 m deep (which is true for DN 150 pipes) work can be carried out without trench side support condition to a fast completion of the construction. Most often, one has to deal with soil sufficiently stable to stay in place for a day or longer. If it is possible to install the pipe and backfill the trench during this period trench-bracing becomes obsolete.

Single-day construction is possible not only for vertically installed pipes (Piggy-Back) but also for Twin-Pipes.

Piggy-Back Laying

At this point the vertical laying of pipes is depicted without reference to additional measures such as compensation or backfilling which most frequently are carried out simultaneously. The sequence of construction is shown schematically in Figure 5-2.

Initially the trench is excavated ①. Onto the fine-grained sand layer ② the bottom pipe is laid ③. Then, the bottom pipe is backfilled ④. The top is installed ⑤ and the pipe trench fully backfilled ⑥.

In order to assure a fluent construction process it is recommended to divide the site into several sections. Even though the construction is one section requires civil and pipe companies to work in an alternating fashion it can still be accomplished to have machinery and personnel working to full capacity by exchanging them between construction sections.

If one is to assess the civil work for the case of vertical arranged pipes versus the one for horizontally laid pipes then the increased difficulties of the deeper and narrower trench become obvious. The difficulties arise from the two-step work of pipe-laying (bottom -> partly refill -> top). For pipe diameters larger than DN 150 two-step bracing of the trench must be considered, also.

Most of these difficulties are completely overcome by hydraulic backfilling which is described in greater detail in the IEA Report on the "Reuse of Excavated Material".

In the case of small pipes with the assumption of appropriate soil conditions no bracing is required. Still, the overall construction costs remain considerably lower for vertically arranged pipes when compared to horizontally arranged ones even if the before described difficulties may lower these savings.

Twin-Pipe

Twin-Pipes are laid such that the supply pipe lies underneath the return pipe. Thereby, the pipe-heat losses are reduced. An example of pipe assembly with drainage, like it is commonly used in Finland, Sweden, and The Netherlands is shown in Figure 5-2.

Fig. 5-2: Mounted Twin-Pipe element with drainage

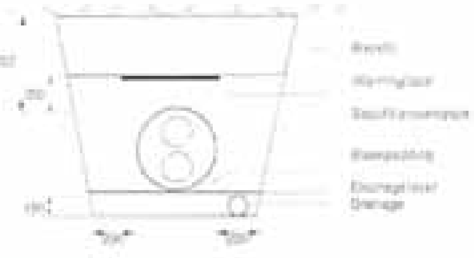
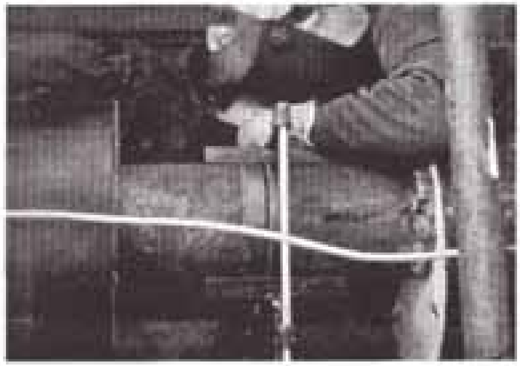
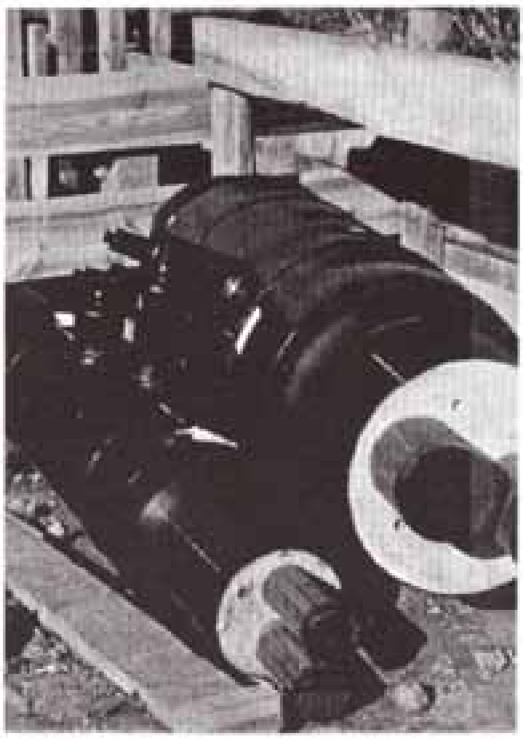


Fig. 5-3: The laying of Twin-Pipes
Left: Welding
Right: Parts



During the process of pipe-welding in the surrounding of the construction site the welder has to pay attention to the tolerances of the supply and return pipe at the same time. This difficulty is generally ranked to important when assessed by outsiders. After a time for accustoming the welders' performance at Twin-Pipes is the same as for single pipes. Fig. 5-3 illustrates a construction site for twin-pipes, at left some valves, on top the welding-process.

Upon requirement it is important to weld fixtures onto Twin-Pipes at the construction site, e. g. at the location of customer service branches. These may be done according to the examples at the bottom of Figure 5-3.



6 Heat Losses

Usually, the heat losses of the pipe network make for a certain part of the operating costs. In the case of Twin-Pipes the fixtures represent a certain heat-bridge by means of which the temperature of the supply and return pipe is somewhat equalized. This effect lowers the temperature difference between the pipes and, in turn, influences the transport-capacity for heat and the amount of cycling water.

6.1 Thermal Insulation in the Ground

For economic reasons district heating pipes installed in Central Europe comply with insulation class 1. In Northern Europe the insulation is thicker, insulation class 3 always applies in Finland. The heat losses of insulation-class 3 insulated pipes are on the order of 20 to 30% lower than those of class 1 insulated ones, while the lower value holds for smaller pipes.

Twin pipes are delivered in one insulation class only. With respect to heat loss this insulation class is even better than insulation class 3, to be specific, heat losses are another 7 to 20% lower where again the lower value applies for smaller pipes. An overview over insulation properties is given by Table 6-1, which gives the annual average heat loss calculated with annual average operation and ambient temperatures (see also Annex II).

If one were to evaluate the advantages in heat loss of the Twin-Pipes one gets different statements depending on whether the comparison was done against class 1 or class 3 insulated single-pipes. For the case of Piggy-Back laid pipes it is assumed that the heat loss is the same than with horizontally laid pipes, not taking into account that the deeper position of the supply line results in reduced heat losses.

Table 6-1: Comparison of heat losses - single pipe of insulation class 1, 3 and Twin-Pipe

Nominal Diameter DN	Class 1 W/m	Class 3 % of Class 1	Twin	
			% of class 1	% of class 3
20	14,7	80	75	93
32	18,4	82	61	74
50	23,6	77	63	81
80	28,9	75	54	72
100	30,5	74	54	73
150	41,9	67	52	78
200	45,6	64	51	80

In the following, the savings due to the reduced heat losses are calculated. The numbers of the heat losses are well known for typical operating conditions, so that one is able to evaluate the differences between the types of pipe. The loss per meter pipe length may be weighted by the price of heat from which the yearly savings follow. These can be converted into present value based on an interest (5%) and the anticipated life-time (25 years). This present value has units of USD/m and may be directly related to other construction costs.

Table 6-2: Cost savings with Twin-Pipes due to reduced heat losses

DN	qV1 [W/m]	dqV [%]	dqV [W/m]	dq [kWh/(m*a)]	Sa [$/(m*a)]	S [$/m]
20	14,7	25	3,7	32,2	0,5	6,9
25	17,7	33	5,8	51,2	0,8	11,0
32	18,4	39	7,2	62,9	1,0	13,8
40	21,0	39	8,2	71,8	1,1	15,5
50	23,6	37	8,7	76,5	1,2	16,5
65	27,8	46	12,8	112,1	1,7	24,2
80	28,9	46	13,3	116,5	1,8	25,1
100	30,5	46	14,0	123,0	1,9	26,5
125	35,3	44	15,5	136,1	2,1	29,4
150	41,9	48	20,1	176,3	2,7	38,0
200	45,6	49	22,3	195,8	3,0	42,2

Legend

Heat Costs [$/MWh] 15,29 1US$=0,9 Euro

Present Worth Factor (5%; 25 a) [-] 14,1

qV1 heat loss of insulation class 1

dqV difference of heat loss of Twin versus insulation class 1

dq annual heat savings

Sa annual heat cost savings

S present worth of saved heat costs (5%; 25 a)

Such a calculation was done in Table 6-2 while insulation class 1 was taken as the reference. An analogous calculation with reference to insulation class 3 is provided in Annex II / A2. However, this calculation was based on a higher heat price (heavy fuel-oil boiler).

6.2 Heat Bridges in the Twin-Pipe

For the Twin-Pipe it has to be estimated what influence the undesirable heat bridges between supply- and return pipe have. The heat is transferred via the fixtures by conduction. The usual fixture-designs have already been illustrated in Figure 3-3. For the design shown in the lower drawing (type 2) the exact dimensions are known so that the transferred heat load Q can be calculated, see Table 6-3.

Table 6-3: Heat conduction through Fixture Type 2

Nominal Diameter DN	Length of Fin mm	Width of Fin mm	Thickness of Fin mm	Power Q W
25	53	50	4	14
32	61	50	4	12
50	80	70	4	13
80	114	110	6	21
100	139	140	6	22
150	208	200	6	24

λ = 46 W/(mK) ΔT = 40 K

The conducted heat flow Q is calculated by the following equation:

$$Q = \lambda \cdot A \cdot \frac{\Delta T}{\delta}$$

with

λ	heat conductivity
A	cross section of fin
ΔT	driving temperature difference
δ	length of fin

Determining the influence of the heat bridges on the overall economy: At first, it will be derived how many bridges (n) it takes to lower the temperature of the supply water by 1 K. Here, it is anticipated that the temperature difference between the lines is 40 K. This would equal 5% equilibration of the imposed temperature difference when using in the returning water also. For fixture-type 2 the number (n) can be calculated. For type 1 it can only be estimated due to the missing dimensional data. It is anticipated that the bridges of type 1 are considerably less efficient (heat conduction higher by factor 3 to 6), see Table 6-4.

Table 6-4: Number of heat bridges for an equilibration of temperatures of 5%

DN	n (type 2)	n (type 1)
25	74	26
32	174	54
50	446	112
80	813	178
100	1548	390
150	4658	784

The result comes out as follows: If the bridges are of type 2 their influence on temperature is small especially if they are only applied at bends, tees etc. If these bridges are of type 1 their effect may not as easily be neglected. A temperature equilibration of 1 up to 2 K seems to be a realistic estimate, if the bridges are also built into the straight pipe sections, refer to the top of Fig. 3-3.

Such a temperature equilibration reduces the heat transport capacity of the network by 2,5 to 5% and, as a consequence, raises the electricity demand for water circulation. (The required electric power for the circulation-pumps rises with the third power of the flow velocity).

Note:
Estimation of the conduction of type 2 fins is based on the assumption that both types have equal cross sections but type 2 fins are considerably smaller by length. Meanwhile, a manufacturer has provided smaller cross sections for type 2 than were taken for the calculation. Due to variations between manufacturers and production dates the planning engineer has to investigate individually if he needs to tackle the relations precisely.

6.3 Cost Estimate

From the estimate of the previous sections it becomes obvious which high degree of inherent uncertainty these cost-calculations over the life-span of a district heating grid possesses. They are governed by factors that are hard to foresee mainly by the interest on invested capital, the heat price and the expected life-time.

- with respect to heat loss vertically installed pipes are equal to horizontally laid pipes.
- referring to heat loss Twin-Pipes are favorable over single-pipes.

In Table 6-2 a cost benefit of the Twin-Pipe per meter pipe route was calculated which has to be seen under the restrictions of chapter 7. Letting caution prevail upon these calculations it is recommended not to take more than 50% of the calculated cost benefits into account when doing actual cost comparisons. This procedure results in cost benefits of the Twin system compared to the others of about 1 to 3% related to overall costs, for further details see chapter 7.

In the end it is the responsibility of the planning engineer to decide to what extent to reward credit to the Twin-system for the prospected heat savings.

7 Construction Costs

A comparison of the construction costs for a district heating line may largely depend on the boundary conditions under which the calculation was done. Therefore, the conditions have been thoroughly chosen and it has been utilized only a single scheme of calculation one for Finland and one for Germany, which has been proved valuable in similar comparisons.

The comparison aimed to clarify the cost situations of

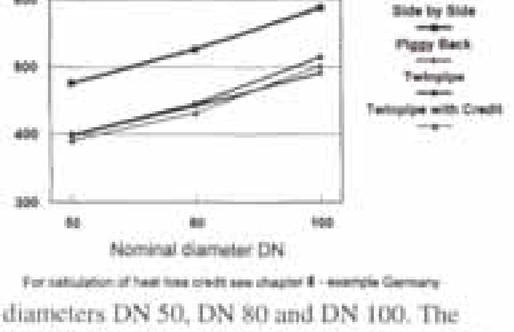
- the pipe arrangement: Side-by-Side, Piggy-Back, Twin
- the type of trench: vertical walls, sloped walls (slope ratio 1:5)
- the level of civil costs: high - exp. Germany; low - exp. Finland

The outcome of this calculation is provided in the following two sections. In section 7.1 the arrangement of pipes and the trench type with respect to German price level are dealt with; in section 7.2 only the arrangement of pipes in the sloped trench is focused on while the Finish civil costs are being applied.

7.1 Comparison with Elevated Prices for Civil Work - Example Germany

The cost calculations were carried out for a pipe route of 100 m length for each of the pipe

Fig. 7-1: Construction costs for horizontally, vertically laid pipes and Twin-Pipes - example Germany (in street areas)



For calculation of heat loss credit see chapter 8 - example Germany

diameters DN 50, DN 80 and DN 100. The trench side support was a simple bracing of the upper section of the trench. The thickness of the asphalt layer was assumed to be 20 cm of which 16 cm were bituminous sublayer and 4 cm were wear layer. No extra costs were considered for prestressing of the pipes (Side-by-Side, Piggy-Back, Twin). If the pipes were to be prestressed costs would rise for every type of system by equal amounts.

The calculation was done by taking prices from the annual standard price catalogue for the major cost items. These prices reflect many years of experience and have been based on projects for which a standard bidding procedure had been used. However, price differences occur even throughout Germany and therefore data are characterized by some margin of uncertainty. The general pattern of such a calculation is supplied in Annex I.

The results of this calculation are shown in Figure 7-1.

The diagram outlines the costs for the three alternative pipe arrangements inside a trench with vertical walls and simple bracing.

The German cost comparison relates primarily to the pure construction costs since these are predictable with a low margin of uncertainty. The costs are represented by the major lines in Figure 7-1. In addition, the Twin-Pipe has to receive credit for the lower losses with their amount recommended in section 6.3. The line for the resulting costs is printed a little finer in Figure 7-1.

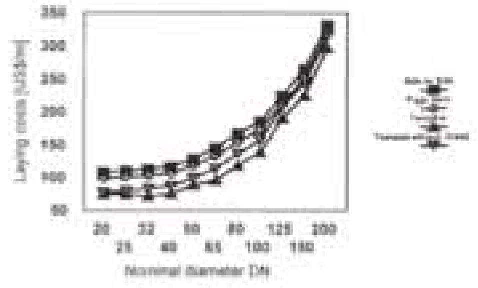
If one evaluates the pure construction costs results show that the Piggy-Back laying and the Twin-System have considerable economic advantages when compared with horizontally arranged pipes. The Piggy-Back laying almost equals the Twin-System in costs while a slight advantage may be encountered for larger pipe diameters.

The sloped trench is more expensive in Germany because it requires enlarged masses to be excavated, backfilled and restored. The sloped trench favorites the Twin-Pipe over the Piggy-Back laying for the reason of a shallower trench. However, in Germany it is pointless to lay the pipes inside a sloped trench in an inner city-area.

7.2 Comparison with Low Prices for Civil Work - Example Finland

An analogous calculation of the construction costs of the 3 alternative systems was worked out and based on the Finish price relations. Only sloped trenches were considered and a different model network was assumed. The

Fig. 7-2: Construction cost for horizontally and vertically laid pipes and Twin-Pipes - Example Finland (in street areas)



complete calculation is attached in Annex II. The calculations were made for situations in the city-street area and in unpaved terrain. The results for the city-street area are shown in Figure 7-2.

Fig. 7-3: Construction costs of the new laying technologies for Germany

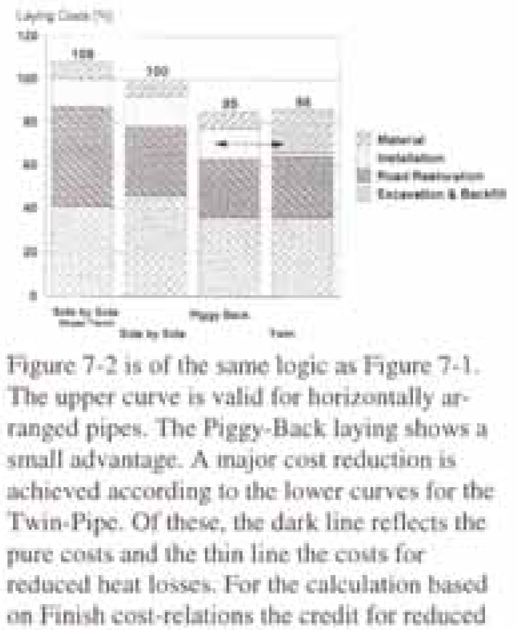


Figure 7-2 is of the same logic as Figure 7-1. The upper curve is valid for horizontally arranged pipes. The Piggy-Back laying shows a small advantage. A major cost reduction is achieved according to the lower curves for the Twin-Pipe. Of these, the dark line reflects the pure costs and the thin line the costs for reduced heat losses. For the calculation based on Finish cost-relations the credit for reduced heat losses has a major influence on the overall costs.

Note:
The large differences in civil costs between the countries Finland and Germany lead to the well-known differences in overall construction costs. E.g., the civil costs of a DN 100 pipe amount to 588 US$/m in Germany as opposed to only 185 US$/m in Finland. Fig. 7-3 provides these cost-relations in greater detail.

7.3 Assessment

The comparison impressively supports the cost advantage of Piggy-Back and Twin-Pipe systems over horizontally laid pipes. The considered new techniques are beneficial as compared to the horizontal laying in the shallow trench throughout the entire range of diameters that have been investigated. While often times it is difficult to achieve saving of even 3% with purely technical improvements, here, a potential for savings of 10 to 20% has opened up to a nominal diameter of DN 200 - and even larger for the case of Piggy-Back laying.

As is supported by the cost diagrams savings vary with respect to diameter. To enhance the cost-comparison, at this point, reference numbers are formed that reflect the construction cost of a mix of 3 pipe diameters, i.e. the length-shares

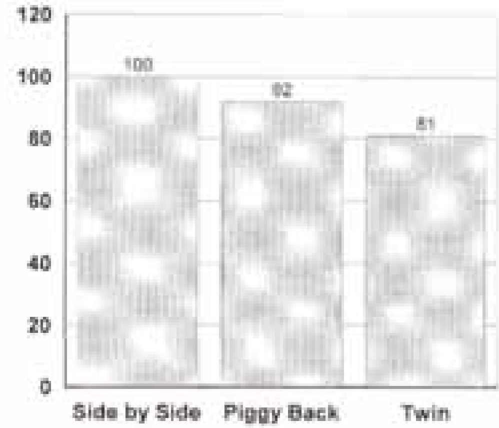
	265 m DN 50
	145 m DN 80
	100 m DN 100
Total	510 m

First, these reference numbers are evaluated for German cost conditions. If one judges the result as a whole starting off from the reference case of Side-by-Side laying (100%) the Piggy-Back and Twin-Systems come out with savings of about 15%, see Figure 7-3.

The Piggy-Back laying technique seems to be a little better than the Twin-System: The left bar accounts for a sloped trench. It is proved that under German cost conditions and with paved street surfaces the sloping of a trench is not useful.

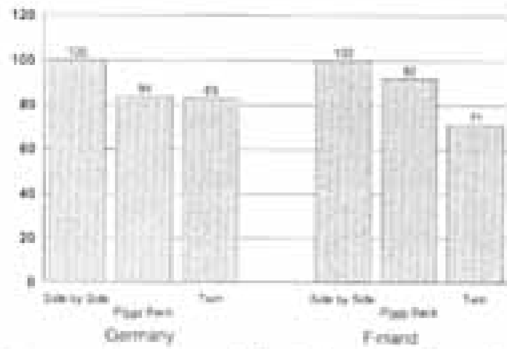
(Explanation: For the two right columns the cost-shares for installation and material are taken from two different price catalogues, in which the cost items mainly for transportation are divided differently.)

Fig. 7-4 (right): Construction costs of the new laying technologies in Finland



In Finland the Twin-Pipe offers an equally great cost benefit as in Germany. The Piggy-Back laying only offers a small benefit of 8%, as may be seen in Fig. 7-4. But for pipe diameters larger than DN 200 Piggy-Back laying is the only viable alternative.

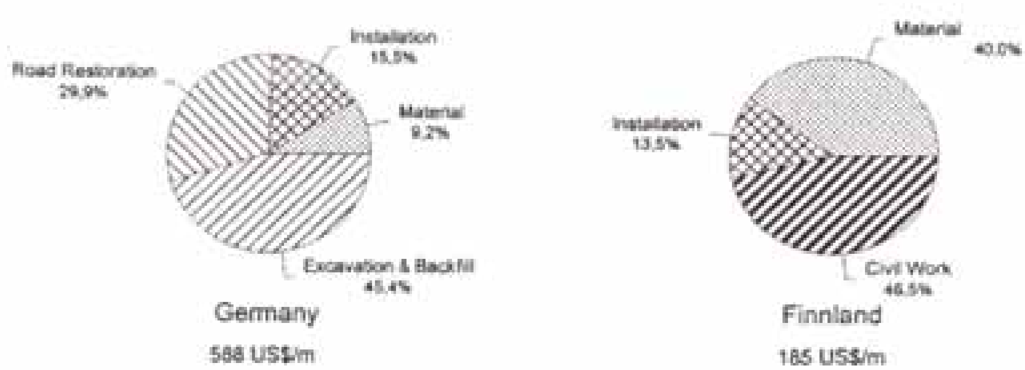
Fig. 7-5: Cost comparison of the new laying technologies accrediting the different insulation properties



Because the compared Pipe-Systems differ with respect to heat loss the Twin-Pipe was credited the savings which arise from the reduced heat losses in the following Figure. These savings are evaluated on grounds of the particular country-specific calculation, refer to chapter 6.

Figure 7-5 provides the cost comparison of the two new laying technologies for the installation in the street area accrediting the different insulation properties. For the example of Germany a high level of civil-work prices applies and the trench is built with vertical walls. The example Finland means low civil-work prices and sloped trench walls.

Fig. 7-6: Distribution of costs for pipe-construction in Finland and Germany



Literature

[1] EN 253
Preinsulated bonded pipe systems for underground hot water networks
Pipe assembly of steel pipes, polyurethane thermal insulation and outer casing of high density polyethylene, 1994

[2] EN 448
Preinsulated bonded pipe systems for underground hot water networks
Fittings assemblies of steel service pipes, polyurethane thermal insulation and outer casing of high density polyethylene

[3] EN 488
Preinsulated bonded pipe systems for underground hot water networks
Steel valve assembly for steel service pipes, polyurethane thermal insulation and outer casing of high density polyethylene

[4] EN 489
Preinsulated bonded pipe systems for underdground hot water networks
Joint assembly for steel service pipes, polyurethane thermal insulation and outer casing of high density polyethylene

[5] Randløv, P.
District heating handbook
European district heating pipe manufacturers association, DK-Fredericia 1997

[6] AGFW-Arbeitsblatt FW 401 - Entwurf
Verlegung und Statik von Kunstoff-Mantelrohren (KMR) für Fernwärmenetze
Arbeitsgemeinschaft Fernwärme e. V. - AGFW, D-Frankfurt 1997

[7] CEN TC 107/TC 267/JWG 1
Design and installation of preinsulated bonded pipes for district heating
Draft standard

[8] Hoffmann, H.-Werner.; Schmitt, F.
Cold Installation of Rigid District Heating Pipes
IEA District Heating & Cooling, Report 1999:T3.1

[9] Hoffmann, H.-W.
Neuartige Verlegetechniken für das Kunstoff-Verbundmantelrohrsystem - Abschlußbericht
MVV Mannheimer Versorgungs- und Verkehrsgesellschaft, D-Mannheim 1995

[10] Läggningsanvisningar för fjärrvärmerör
FVF Stockholm, D:211, November 1998

Appendices

Original material – not translated

Annex I:	MVV Cost Calculation Example DN 50 1. Side-by-Side 2. Piggy Back 3. Twinpipe
Annex II	EKONO - Report New Ways of Laying Pipes – Savings and Benefits Achievable with Twin Pipe

Kalkulation

Projekt: | Ort/Beschreibung: **IEA-Preisvergleich** | Projekt-Nr.: 3301182

Position	Bezeichnung der Leistung	Einheit	Menge Dim.1	Dim.2	Dim.3	GesMenge	Einzelpreis	Zuschl%	Abschl%	Kontierung 1 %1	Betrag	Kontierung 2 %2	Betrag	Kontierung 3 %3	Betrag	GesBetrag
102.010.0105	Asphaltbeton 0/8 mm einbauen	M3	100,000	1,000	0,040	4,000	1.092,55			100	4.370,20					4.370,20
102.010.0106	Bitu Decke 4 cm T schneiden	M	200,000	1,000	1,000	200,000	30,65			100	6.130,00					6.130,00
																65.005,15
A1.001	**- Zusammenfassung**															
G102	**Gewerk: Tiefbauarbeiten**															**65.005,15**
	Summe Abschnitt 1.001										**65.005,15**					**65.005,15**
A1.002																
G130	**Rohrbauarbeiten, Bereich Fernw.**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				
T130.100																
130.100.0020	Zusätzliche Materialtransporte	PS	1,000	1,000	1,000	1,000	184,50			100	184,50					184,50
130.100.0103	Abladen Rohr Fertigteil DN 50	M	204,000	1,000	1,000	204,000	3,20			100	652,80					652,80
130.100.0203	KMR verl. geschalt. Grab. DN 50	M	200,000	1,000	1,000	200,000	42,55			100	8.510,00					8.510,00
130.100.0303	KMR verl. ungeschalt. Grab. DN 50	M		1,000	1,000		37,20			100						0,00
T130.400	**Schweißen und Schneiden**															
130.400.0003	Rohrschnitte Gehrung DN 50	ST	2,000	1,000	1,000	2,000	32,35			100	64,70					64,70
130.400.0103	KMR Abmantelung DN 50	ST	2,000	1,000	1,000	2,000	32,23			100	64,46					64,46
130.400.0203	Rundschweißung Segment DN 50	ST	18,000	1,000	1,000	18,000	52,60			100	946,80					946,80
																10.423,26
A1.002	**- Zusammenfassung**															
G130	**Rohrbauarbeiten, Bereich Fernw.**															**10.423,26**
	Summe Abschnitt 1.002										**10.423,26**					**10.423,26**
A1.003																
G900	**Zusatz-Gewerk**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				
T900.100	**Material**															
900.100.0010	Material	DM	5.253,000	1,000	1,000	5.253,000	1,00			100	5.253,00					5.253,00
T900.200	**Löhne und Gehälter**															
900.200.0010	Eigene Löhne und Gehälter	DM		1,000	1,000		1,00			100						0,00
T900.300	**Fahrzeuge und Geräte**															
900.300.0010	Eigene Fahrzeuge und Geräte	DM		1,000	1,000		1,00			100						0,00
T900.400	**Bauleitung**															
900.400.0010	Planung und Bauaufsicht	DM		1,000	1,000		1,00			100						0,00
																5.253,00
A1.003	**- Zusammenfassung**															
G900	**Zusatz-Gewerk**															**5.253,00**

Kalkulation

Projekt: Ort/Beschreibung: **IEA-Preisvergleich** Projekt-Nr.: 3301182

Position	Bezeichnung der Leistung	Einheit	Menge Dim.1	Dim.2	Dim.3	GesMenge	Einzelpreis	Zuschl%	Abschl%	Kontierung 1 %1	Betrag	Kontierung 2 %2	Betrag	Kontierung 3 %3	Betrag	GesBetrag
	Summe Abschnitt 1.003										**5.253,00**					**5.253,00**
B1	**NEBENEINANDER VERBAU DN 50 - Zusammenfassung**															
A1.001																**65.005,15**
A1.002																**10.423,26**
A1.003																**5.253,00**
	Summe Bereich 1										**80.681,41**					**80.681,41**
B2	**ÜBEREINANDER VERBAU DN 50**															
A2.001																
G102	**Gewerk: Tiefbauarbeiten**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				
T102.001	**Aufbruch- u Oberbodenarbeiten**															
V102.001.010	Aufbrech. v. bitum. Verkehrsfläch.															
102.001.0103	0 - 20 cm Stärke Grabenbereich	M3	100,000	0,425	0,200	8,500	573,10			100	4.871,35					4.871,35
102.001.0108	0 - 20 cm Randstreifenbereich	M3	100,000	0,300	0,200	6,000	781,94			100	4.691,64					4.691,64
V102.001.050	Vergütung der Deponiegebühren															
102.001.0502	Verunreinigter Aushub	T	31,870	1,000	1,900	60,553	86,39			100	5.231,17					5.231,17
102.001.0503	Beton oder Straßenaufbruch	T	14,500	1,000	2,200	31,900	19,60			100	625,24					625,24
T102.002	**Erdaushub für Leitungsgräben**															
102.002.0101	Aushub Masch., T 1,25 m, Klasse 3 - 4	M3	46,370	1,000	1,000	46,370	89,68			100	4.158,46					4.158,46
T102.005	**Verbauarbeiten**															
102.005.0001	Saumbohlen	M	100,000	1,000	1,000	100,000	58,80			100	5.880,00					5.880,00
T102.006	**Transport von Aushub**															
102.006.0001	Aushub aufladen, abfahren	M3	46,370	1,000	1,000	46,370	49,85			100	2.311,54					2.311,54
T102.007	**Liefern Auffüllmaterial**															
102.007.0002	Sand bis 4 mm	M3	29,420	1,000	1,000	29,420	51,70			100	1.521,01					1.521,01
T102.010	**Wiederherstellung Oberflächen**															
V102.010.000	U.bau, Planum für Flächen > 10 m2															
102.010.0004	Herst. Feinplanums	M2	72,500	1,000	1,000	72,500	7,15			100	518,38					518,38
V102.010.010	Bituminöse Fahrbahndecken															
102.010.0101	Lief. Einbau. Bitu. Tragschl.	M3	72,500	1,000	0,160	11,600	762,59			100	8.846,04					8.846,04
102.010.0103	Lief. Einbau. Tokbänder	M	200,000	1,000	1,000	200,000	19,70			100	3.940,00					3.940,00
102.010.0105	Asphaltbeton 0/8 mm einbauen	M3	72,500	1,000	0,040	2,900	1.092,55			100	3.168,40					3.168,40
102.010.0106	Bitu Decke 4 cm T schneiden	M	200,000	1,000	1,000	200,000	30,65			100	6.130,00					6.130,00
																51.893,23
A2.001	**- Zusammenfassung**															

Kalkulation

Projekt: Ort/Beschreibung: **IEA-Preisvergleich** Projekt-Nr.: 3301182

Position	Bezeichnung der Leistung	Einheit	Menge Dim.1	Dim.2	Dim.3	GesMenge	Einzelpreis	Zuschl%	Abschl%	Kontierung 1 %1	Betrag	Kontierung 2 %2	Betrag	Kontierung 3 %3	Betrag	GesBetrag
G102	**Gewerk: Tiefbauarbeiten**															**51.893,23**
	Summe Abschnitt 2.001										**51.893,23**					**51.893,23**
A2.002																
G130	**Rohrbauarbeiten, Bereich Fernw.**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				
T130.100																
130.100.0020	Zusätzliche Materialtransporte	PS	1,000	1,000	1,000	1,000	184,50			100	184,50					184,50
130.100.0103	Abladen Rohr Fertigteil DN 50	M	204,000	1,000	1,000	204,000	3,20			100	652,80					652,80
130.100.0203	KMR verl. geschalt. Grab. DN 50	M	200,000	1,000	1,000	200,000	42,55			100	8.510,00					8.510,00
130.100.0303	KMR verl. ungeschalt. Grab. DN 50	M		1,000	1,000		37,20			100						0,00
T130.400	**Schweißen und Schneiden**															
130.400.0003	Rohrschnitte Gehrung DN 50	ST	2,000	1,000	1,000	2,000	32,35			100	64,70					64,70
130.400.0103	KMR Abmantelung DN 50	ST	2,000	1,000	1,000	2,000	32,23			100	64,46					64,46
130.400.0203	Rundschweißung Segment DN 50	ST	18,000	1,000	1,000	18,000	52,60			100	946,80					946,80
																10.423,26
A2.002	**- Zusammenfassung**															
G130	**Rohrbauarbeiten, Bereich Fernw.**															**10.423,26**
	Summe Abschnitt 2.002										**10.423,26**					**10.423,26**
A2.003																
G900	**Zusatz-Gewerk**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				
T900.100	**Material**															
900.100.0010	Material	DM	5.253,000	1,000	1,000	5.253,000	1,00			100	5.253,00					5.253,00
T900.200	**Löhne und Gehälter**															
900.200.0010	Eigene Löhne und Gehälter	DM		1,000	1,000		1,00			100						0,00
T900.300	**Fahrzeuge und Geräte**															
900.300.0010	Eigene Fahrzeuge und Geräte	DM		1,000	1,000		1,00			100						0,00
T900.400	**Bauleitung**															
900.400.0010	Planung und Bauaufsicht	DM		1,000	1,000		1,00			100						0,00
																5.253,00
A2.003	**- Zusammenfassung**															
G900	**Zusatz-Gewerk**															**5.253,00**
	Summe Abschnitt 2.003										**5.253,00**					**5.253,00**
B2	**ÜBEREINANDER VERBAU DN 50 - Zusammenfassung**															
A2.001																51.893,23
A2.002																10.423,26
A2.003																5.253,00

Kalkulation

Projekt: Ort/Beschreibung: IEA-Preisvergleich Projekt-Nr.: 3301182

Position	Bezeichnung der Leistung	Einheit	Menge Dim.1	Dim.2	Dim.3	GesMenge	Einzelpreis	Zuschl%	Abschl%	Kontierung 1 %1	Betrag	Kontierung 2 %2	Betrag	Kontierung 3 %3	Betrag	GesBetrag
	Summe Bereich 2										**67.569,49**					**67.569,49**
B3	**TWIN VERBAU DN 50**															
A3.001																
G102	**Gewerk: Tiefbauarbeiten**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				
T102.001	**Aufbruch- u Oberbodenarbeiten**															
V102.001.010	Aufbrech. v. bitum. Verkehrsfläch.															
102.001.0103	0 - 20 cm Stärke Grabenbereich	M3	100,000	0,500	0,200	10,000	573,10			100	5.731,00					5.731,00
102.001.0106	0 - 20 cm Randstreifenbereich	M3	100,000	0,300	0,200	6,000	781,94			100	4.691,64					4.691,64
V102.001.050	Vergütung der Deponiegebühren															
102.001.0502	Verunreinigter Aushub	T	27,500	1,000	1,900	52,250	86,39			100	4.513,88					4.513,88
102.001.0503	Beton oder Straßenaufbruch	T	16,000	1,000	2,200	35,200	19,60			100	689,92					689,92
T102.002	**Erdaushub für Leitungsgräben**															
102.002.0101	Aushub Masch., T 1,25 m, Klasse 3 - 4	M3	43,500	1,000	1,000	43,500	89,68			100	3.901,08					3.901,08
T102.005	**Verbauarbeiten**															
102.005.0001	Saumbohlen	M	100,000	1,000	1,000	100,000	58,80			100	5.880,00					5.880,00
T102.006	**Transport von Aushub**															
102.006.0001	Aushub aufladen, abfahren	M3	43,500	1,000	1,000	43,500	49,85			100	2.168,48					2.168,48
T102.007	**Liefern Auffüllmaterial**															
102.007.0002	Sand bis 4 mm	M3	24,360	1,000	1,000	24,360	51,70			100	1.259,41					1.259,41
T102.010	**Wiederherstellung Oberflächen**															
V102.010.000	U.bau, Planum für Flächen > 10 m2															
102.010.0004	Herst. Feinplanums	M2	80,000	1,000	1,000	80,000	7,15			100	572,00					572,00
V102.010.010	Bituminöse Fahrbahndecken															
102.010.0101	Lief. Einbau. Bitu. Tragschi.	M3	80,000	1,000	0,160	12,800	762,59			100	9.761,15					9.761,15
102.010.0103	Lief. Einbau. Tokbänder	M	200,000	1,000	1,000	200,000	19,70			100	3.940,00					3.940,00
102.010.0105	Asphaltbeton 0/8 mm einbauen	M3	80,000	1,000	0,040	3,200	1.092,55			100	3.496,16					3.496,16
102.010.0106	Bitu Decke 4 cm T schneiden	M	200,000	1,000	1,000	200,000	30,65			100	6.130,00					6.130,00
																52.734,72
A3.001	**- Zusammenfassung**															
G102	**Gewerk: Tiefbauarbeiten**															**52.734,72**
	Summe Abschnitt 3.001										**52.734,72**					**52.734,72**
A3.002																
G130	**Rohrbauarbeiten, Bereich Fernw.**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:					Auftrag 3, Nr.:				

Kalkulation

Projekt: Ort/Beschreibung: **IEA-Preisvergleich** Projekt-Nr.: 3301182

Position	Bezeichnung der Leistung	Einheit	Dim.1	Dim.2	Dim.3	GesMenge	Einzelpreis	Zuschl%	Abschl%	%1	Kontierung 1 Betrag	%2	Kontierung 2 Betrag	%3	Kontierung 3 Betrag	GesBetrag
T130.100																
130.100.0020	Zusätzliche Materialtransporte	PS	1,000	1,000	1,000	1,000	184,50			100	184,50					184,50
130.100.0106	Abladen Rohr Fertigteil DN 100	M					6,00			100						0,00
130.100.0206	KMR verl. geschalt. Grab. DN 100	M					61,00			100						0,00
T130.400	**Schweißen und Schneiden**															
130.400.0003	Rohrschnitte Gehrung DN 50	ST	2,000	1,000	1,000	2,000	32,35	10,00		100	71,17					71,17
130.400.0106	KMR Abmantelung DN 100	ST	1,000	1,000	1,000	1,000	42,90	10,00		100	47,19					47,19
130.400.0203	Rundschweißung Segment DN 50	ST	18,000	1,000	1,000	18,000	52,60	10,00		100	1.041,48					1.041,48
																1.344,34
A3.002	**- Zusammenfassung**															
G130	**Rohrbauarbeiten, Bereich Fernw.**															**1.344,34**
	Summe Abschnitt 3.002										**1.344,34**					**1.344,34**
A3.003																
G900	**Zusatz-Gewerk**	Aufteilung auf:	Auftrag 1, Nr.:				Auftrag 2, Nr.:				Auftrag 3, Nr.:					
T900.100	**Material**															
900.100.0010	Material	DM	1.376,400	1,000	10,000	13.764,000	1,00			100	13.764,00					13.764,00
T900.200	**Löhne und Gehälter**															
900.200.0010	Eigene Löhne und Gehälter	DM		1,000	1,000		1,00			100						0,00
T900.300	**Fahrzeuge und Geräte**															
900.300.0010	Eigene Fahrzeuge und Geräte	DM		1,000	1,000		1,00			100						0,00
T900.400	**Bauleitung**															
900.400.0010	Planung und Bauaufsicht	DM		1,000	1,000		1,00			100						0,00
																13.764,00
A3.003	**- Zusammenfassung**															
G900	**Zusatz-Gewerk**															**13.764,00**
	Summe Abschnitt 3.003										**13.764,00**					**13.764,00**
B3	TWIN VERBAU DN 50 - Zusammenfassung															
A3.001																52.734,72
A3.002																1.344,34
A3.003																13.764,00
	Summe Bereich 3										**67.843,06**					
																67.843,06

Annex II: Ekono Report

1 GENERAL

Total costs of constructing the district heating network consist of excavation, installation, material and filling cost. Most of these costs depend on the time used. Therefore cutting the total time used in construction and installation is an effective way to decrease the total costs.

The average costs of district heating network construction in Finland in year 1996 are shown cumulatively in Figure 1. Total costs are divided into material costs, excavation costs, pipe work costs and filling layer costs.

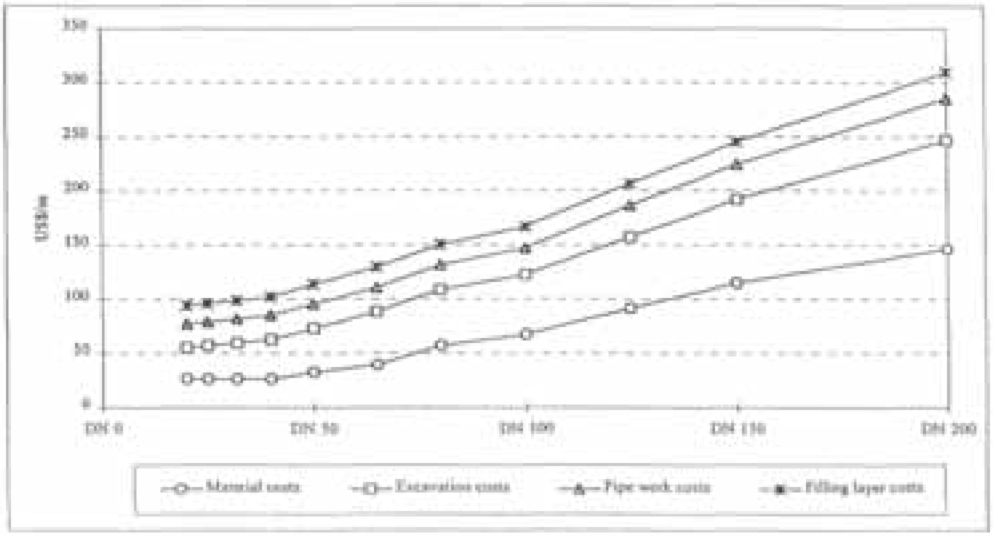


Figure 1. Cumulative average district heating network construction costs in Finland in 1996 by pipe diameter. Single pipes, grass area.

1.1 Twin-pipe element

Twin-pipes are manufactured according to the same standards as single pipes with very few additional specifications, especially on the tolerances of the pipe ends. Twin-pipes are installed in the No Comp technique while they are preheated. Expansion bends and expansion pads are not needed.

In the twin-pipe element, the two steel pipes are located inside the same casing pipe. In manufacturing there are different practises among manufactures. Some use welded steel plates as distance holders. Some manufacturers use welded steel plates only in straight pipe element pipelines DN 100 and larger but in smaller sizes they use similar plastic spacer construction (modified for twin pipe) as for single pipes. The thickness of the plates varies also between manufacturers. At fittings as bends, T-branches and valve-elements steel pipes are always fixed together. It would be sufficient when pipes are bonded only by the PUR-foam.

1.2 Construction costs

Especially in small pipe diameter range about 50 % of total cost are construction costs. In larger diameter range, the percentage of material costs increases, although construction still covers 30-40% of total costs. Twin pipe elements require less voluminous excavation than single pipe systems. Therefore, savings can be achieved by reducing the soil masses handled in construction.

When the larger diameter pipes (> DN 125) are used, the percentage of material costs increases: the larger the diameter of the pipe, the smaller is the percentage of the construction costs. Finally, the real conditions, as the quality of the soil, extent of the contract and purchase prices determine the actual final costs.

1.3 Planning

In preliminary planning the routing, trench type and accessory equipment are determined along with dimensioning the network. Routing has a significant effect on total costs: the shorter the pipe length, the lower the costs.

Especially in small pipe diameter range, the expenses can be cut by using the twin pipe elements.

The use of longer pipes reduces the number of the joints and weld runs. When the pipe length is 16 m instead of 12 m, the number of joints decreases 25%.

Currently it is possible to determine the heat demand of the consumers quite accurately. So the network can be designed economically, for example allowing the pressure losses increase in the non-critical parts of the network. Unfortunately this is possible only in traditional small networks, where pumping site is locked. In larger networks pumping and the critical point are not constant, which makes the optimisation more complicated.

2 USE OF TWIN PIPE ELEMENT

2.1 Present situation

In last few years the use of twin pipe system has increased year by year. The share (trench length) of twin pipe element deliveries of all (including export) pipe deliveries in 1996 for two pipe suppliers in Finland. KWH Tech Ltd. and ABB Ecopipe Ltd. were as follows:

	KWH Tech Ltd.	ABB Ecopipe Ltd.
DN 20	67 %	70 %
DN 25	58 %	55 %
DN 32	65 %	46 %
DN 40	43 %	62 %
DN 50	37 %	74 %
DN 65	35 %	48 %
DN 80	25 %	43 %
DN 100	13 %	20 %
DN 125	25 %	37 %
DN 150	9 %	10 %
DN 200	18 %	8 %

During the first half of year 1998 the share of twin pipes has been increasing significantly proving the economy of using twin pipes in Finland.

2.2 Construction costs

When the single pipes are installed in the trench horizontally, the branches have to cross the main line above it, as shown in Figure 2. The standard burial depth of the main line in Finland is 600 mm (h in Figure 2). The actual burial depth is then determined by the branches (h' in Figure 2). Thus, the burial depth of the branch varies along the branch pipe diameter. The vertical distance between the main line and the branch is 35 mm.

In the twin pipe system the mainline pipe determines the burial depth. The branches connect to the mainline laterally. Therefore the burial depth is smaller, 450 mm.

When comparing the construction costs of twin pipe elements to single pipes, the total costs of twin pipes in small diameter range are 30-35% smaller in uncovered (grass) areas and coated (asphalt) areas than single pipe costs. In larger size range 10-20% savings are achieved. The twin pipe elements are installed in trench using the minimum protection distance (100 mm). In that case the pipes are connected before installing into the trench. The volume of theoretical trenches is calculated in Annex 1.

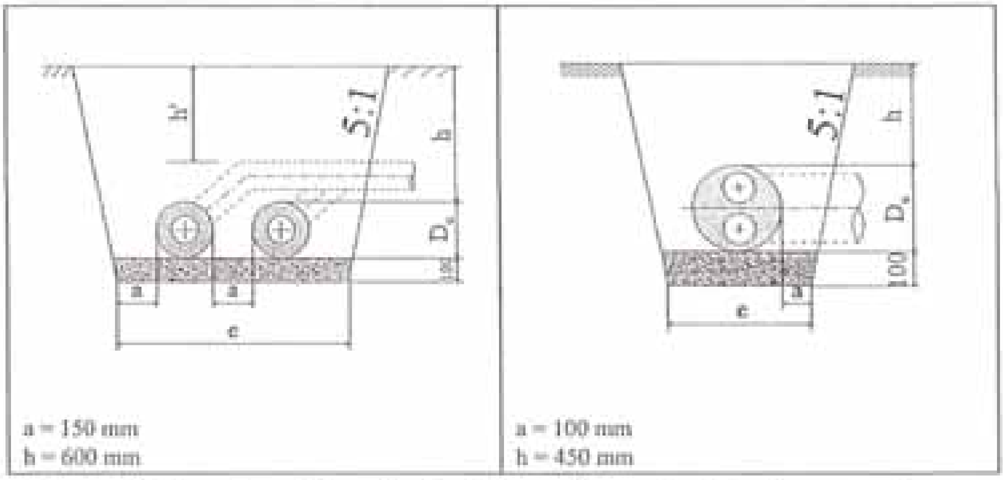


Figure 2. Branches of two single pipes and a twin pipe element.
h = burial depth of the main line
h' = burial depth of branches
a = protection distance

2.3 Thermal loss

There is more insulation material in twin pipes because of larger volume of the element. On the other hand, the surface area of two single pipe elements is larger than surface of twin pipe element. Therefore the twin pipe system's thermal losses are much smaller than in single pipe system. Using the twin pipe system reduces heat loss 10-20% in small diameter range and nearly 30% in large diameter range. The value of heat loss is calculated by 5% rate of interest, 25 years repayment period and 21.8 USD/MWh heat price (heavy fuel oil as peak load): the discounted savings will be about 22 USD/m. For more details, see Annex 2.

For single pipes the heat losses are calculated by using installation class 3, which recommended by Finnish DH-association. The insulation thicknesses are as follows:

	Thickness
DN 20	46 mm
DN 25	43 mm
DN 32	46 mm
DN 40	43 mm
DN 50	47 mm
DN 65	49 mm
DN 80	52 mm
DN 100	64 mm
DN 125	66 mm
DN 150	68 mm

If the heat loss comparison is done by using the insulation thickness in Middle Europe, the saving by using twin pipes would be even greater.

2.4 Material costs

Savings in material costs achieved by using twin pipes result from savings in element costs and smaller amount of components and joints. The Z-bends are not normally used in the branches and so the length of the branches becomes shorter. Also fewer joints and bends are needed.

2.5 Civil Engineering Costs

When twin pipes are used, the depth and width of the trench are smaller than for single pipe trench. When comparing the masses handled in single pipe trench with protecting layer of 150 mm to twin pipe trench with protecting layer 150 mm, savings in costs are achieved up to pipe size DN150, when burial depth is 400 mm. When burial depth is 500 mm, savings in costs are achieved up to pipe size DN 125. With a protection layer of 100 mm for twin pipe, savings are achieved in all pipe sizes (up to DN 200) and up to pipe sizes DN 150, respectively. These figures and the same comparison for protection layer of 100 mm for single pipe system are presented in the Table 1. Estimations are calculated with theoretical trench.

Table 1. Savings in excavation costs achieved up to pipe size X when using twin pipes instead of horizontal single pipes.

Single pipes horizontally		Twin pipes			
		a = 100		a = 150	
		h = 400	h = 500	h = 400	h = 500
h = 600	a = 100	DN 150	DN 125	DN 125	DN 100
h = 600	a = 150	DN 200	DN 150	DN 150	DN 125

Further, when the pipe size is smaller than DN 200, less casing is needed when using the twin pipe elements. In practice, the depth of the trench depends on the actual site and branching of the network. The comparison calculations of the burial depth and protection distance are presented in Annex 1.

2.6 Maintenance

It is likely that the maintenance costs are smaller when using twin pipe elements. That is because there is no substantial thermal expansion in the element during normal operation. The pipes are located in the same casing and tied together with polyurethane. This prevents the opposite movements of the pipes. Therefore the stress on the joints, tapping and bends is much smaller than in single pipe system. This also allows the use of thinner protection layer, 100 mm for twin pipe element.

The facts before indicate that it is feasible to increase the use of twin pipe systems in the pipe diameter range up to DN 150-200. The thermal loss and maintenance costs should be taken into consideration, when selecting the element type. In bigger sizes the larger diameter of the twin pipe element sets certain limitations especially in the areas whit large number of crossing services.

3 DIFFERENT TECHNIQUES

3.1 Pre-stressing pipes during pipe-production

The general practice of installing DH-pipelines is to use a friction fixed piping method. In this method the thermal expansion of the pipe elements is prevented by soil friction. Because of the temperature changes the stresses in the pipes increase. Prestressing by preheating before back-filling is required to avoid overcompression during operation. This lengthens the installation time needed and thereby the construction costs increase.

In twin pipe systems the pre-stressing can be done in a following procedure. The pipes are prestressed by keeping them in different temperatures during bonding them with PUR-foam in the element production. After the temperature difference equalises, there is tensile stress in the supply pipe and compression stress in the return pipe. The prestressing is secured with temporary anchors, which are cut out after installation (before the casing joint will be done) of the pipeline. The temperatures during operation balance these pre-stresses and so there is no need for preheating during installation.

3.1.1 Demonstration project of prestressed pipes

Kuusankosken Aluelämmitys Ltd carried out the demonstration project during the heating season 1993/1994 in Finland. The transmission line length of 5000 trench meters was constructed by using the new factory-prestressed DH-twin pipe elements in sizes of DN 150 and DN 200. The installation costs totalled only 220 USD/m.

The applicability study of the method was carried out by the Technical Research Centre of Finland. The behaviour of the stresses from pipe factory to maximum operating conditions was monitored by using strain gauges fixed in the steel pipes before factory prestressing and foaming. The monitoring points in the pipeline were selected to cover friction fixed sections and sections near the bends. Installation climate from warm summer to late cold autumn were covered during the demonstration.

The readings provided by the strain gauges showed the following. At an installation temperature of 0°C the stresses were below the lower yield point. At an installation temperature of 15°C or higher the monitored stresses were below lower yield limit with the safety factor of 1.3. The pipe line worked well without any problems during the first heating seasons. To cover all operation conditions monitoring continued through the full heating season.

The advantage of in-factory-prestressed DH-pipe-elements is that no preheating is needed. In that case filling the trench can be started immediately after welding and jointing the pipes in various sections in any order. This reduces significantly the time that the trenches have to be opened during installation. This is a very remarkable benefit especially in city areas, where open trenches disturb the traffic and public.

3.2 Vertically installed single pipes

In Germany to some extent preinsulated pipes are installed vertically one on another. This installation method was developed within the last years and in meanwhile incorporated into German design rules for district heating lines [AGFW FW401]. In the concept branch connections are installed laterally on the mainline, see Figure 3.

If the lower pipeline is chosen to be the return pipe, it can be covered before installing the supply pipe. The supply pipe requires pre-heating, which is done before covering of the whole trench. According to German calculations, this method saves the expenses about 20-30%. The technique is more useful mainly on the areas without many crossing services. This because the pipelines are welded on the top of trench as long preliminary treated sections.

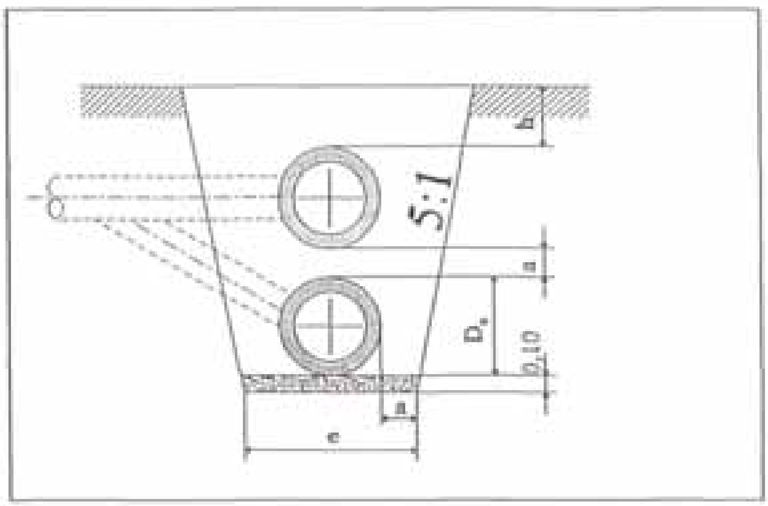


Figure 3. Vertically installed single pipes. In calculations h = 450 mm, a = 100 mm.

4 COST COMPARISON

The average total costs of horizontally installed single pipes, vertically installed single pipes and twin pipes are presented in Table 2. More detailed information about savings when using alternative methods is shown in Annex 3.

The cost comparison is done by designing a model network by all three pipe techniques. The model network is presented in Annex 4.

The design criteria for the model network were as follows:

A. Mechanical

- design temperature of 120°C and pressure 16 bar
- 12 m pipe length
- welding is done outside the trench
- preinsulated branches are used, and twin pipe without Z-bends, single pipes with the z-bends
- no expansion pads are used
- preheating with water as extension of existing system
- leak detection system is included as extensions of the existing system

B. Civil

- thickness of asphalt is 80 mm with 300 mm crushed compacted stone
- initial back filling with 0 - 8 mm sand (100 mm above the casing)
- asphalt is cut back 1.5× the trench width
- grass is cut back 3.0 × the trench width
- top soil thickness on crass 100 mm
- transportation of 8-9 km included
- ditch is done by using slope 1:5 (see Figures 2 and 3)
- no wall supports used
- sand bed thickness 100 mm

Table 2. Average total district heating network costs in green areas (USD/m) for different pipes by pipe size (comparison is done in Finnish cost level). (see Annex 3)

	Single pipes horizontally installed	Single pipes vertically installed	Twin pipes
DN 20	94	89	66
DN 25	96	91	65
DN 32	98	93	60
DN 40	102	96	64
DN 50	114	107	76
DN 65	129	122	82
DN 80	151	143	103
DN 100	167	160	123
DN 125	207	201	173
DN 150	245	241	204
DN 200	309	306	276

The amount of excavation of twin and single pipe system (1)

Protective layer 100 mm

Horisontally installed single pipe: coverage layer of 600 mm on main lines and 400 mm on branches

DN	Du mm	Cross sec. of element m3/m	Trenches [mm] h	see Figure 2 a	 e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	90	0,01	600	100	480	0,50	0,49	0,80
DN 40	110	0,02	600	100	520	0,55	0,53	0,84
DN 50	125	0,02	600	100	550	0,59	0,57	0,88
DN 65	140	0,03	600	100	580	0,63	0,60	0,92
DN 80	160	0,04	600	100	620	0,68	0,64	0,96
DN 100	200	0,06	600	100	700	0,79	0,73	1,06
DN 125	225	0,08	600	100	750	0,86	0,79	1,12
DN 150	250	0,10	600	100	800	0,94	0,84	1,18
DN 200	315	0,16	600	100	930	1,15	0,99	1,34

Vertically installed single pipe: coverage layer of 450 mm on main lines and branches

DN	Du mm	Cross sec. of element m3/m	Trenches [mm] h	see Figure 3 a	 e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	90	0,01	450	100	290	0,38	0,35	0,62
DN 40	110	0,02	450	100	310	0,42	0,38	0,66
DN 50	125	0,02	450	100	325	0,45	0,41	0,69
DN 65	140	0,03	450	100	340	0,49	0,43	0,71
DN 80	160	0,04	450	100	360	0,54	0,46	0,75
DN 100	200	0,06	450	100	400	0,64	0,51	0,82
DN 125	225	0,08	450	100	425	0,71	0,55	0,87
DN 150	250	0,10	450	100	450	0,78	0,59	0,91
DN 200	315	0,16	450	100	515	0,99	0,68	1,03

Twin pipe: coverage layer of 450 mm on main lines and branches

DN	Du	Cross sec. of element m3/m	Trenches [mm] h	see Figure 2 a	 e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	125	0,01	450	100	325	0,31	0,30	0,60
DN 40	160	0,02	450	100	360	0,36	0,34	0,64
DN 50	200	0,03	450	100	400	0,41	0,38	0,70
DN 65	225	0,04	450	100	425	0,45	0,41	0,74
DN 80	250	0,05	450	100	450	0,49	0,44	0,77
DN 100	315	0,08	450	100	515	0,60	0,52	0,86
DN 125	400	0,13	450	100	600	0,75	0,62	0,98
DN 150	500	0,20	450	100	700	0,96	0,76	1,12
DN 200	630	0,31	450	100	830	1,26	0,95	1,30

The amount of excavation of twin and single pipe system (2)

Protective layer 150 mm

Horisontally installed single pipe: coverage layer of 600 mm on main lines and 400 mm on branches

DN	Du	Cross sec. of element	Trenches [mm]			Excavation	Back-filling	Ground surface
			h	a	e			
	mm	m3/m	see Figure 2			m3/m	m3/m	m2/m
DN 25	90	0,01	600	150	630	0,62	0,61	0,95
DN 40	110	0,02	600	150	670	0,67	0,65	0,99
DN 50	125	0,02	600	150	700	0,71	0,69	1,03
DN 65	140	0,03	600	150	730	0,75	0,72	1,07
DN 80	160	0,04	600	150	770	0,81	0,77	1,11
DN 100	200	0,06	600	150	850	0,93	0,86	1,21
DN 125	225	0,08	600	150	900	1,00	0,92	1,27
DN 150	250	0,10	600	150	950	1,08	0,98	1,33
DN 200	315	0,16	600	150	1080	1,30	1,15	1,49

Vertically installed single pipe: coverage layer of 450 mm on main lines and branches

DN	Du	Cross sec. of element	Trenches [mm]			Excavation	Back-filling	Ground surface
			h	a	e			
	mm	m3/m	see Figure 3			m3/m	m3/m	m2/m
DN 25	90	0,01	450	150	390	0,50	0,47	0,74
DN 40	110	0,02	450	150	410	0,55	0,51	0,78
DN 50	125	0,02	450	150	425	0,58	0,54	0,81
DN 65	140	0,03	450	150	440	0,62	0,56	0,83
DN 80	160	0,04	450	150	460	0,68	0,60	0,87
DN 100	200	0,06	450	150	500	0,79	0,67	0,94
DN 125	225	0,08	450	150	525	0,87	0,71	0,99
DN 150	250	0,10	450	150	550	0,95	0,75	1,03
DN 200	315	0,16	450	150	615	1,17	0,86	1,15

Twin pipe: coverage layer of 450 mm on main lines and branches

DN	Du	Cross sec. of element	Trenches [mm]			Excavation	Back-filling	Ground surface
			h	a	e			
		m3/m	see Figure 2			m3/m	m3/m	m2/m
DN 25	125	0,01	450	150	425	0,38	0,37	0,70
DN 40	160	0,02	450	150	460	0,43	0,41	0,74
DN 50	200	0,03	450	150	500	0,49	0,46	0,80
DN 65	225	0,04	450	150	525	0,53	0,49	0,84
DN 80	250	0,05	450	150	550	0,57	0,52	0,87
DN 100	315	0,08	450	150	615	0,68	0,60	0,96
DN 125	400	0,13	450	150	700	0,85	0,72	1,08
DN 150	500	0,20	450	150	800	1,06	0,86	1,22
DN 200	630	0,31	450	150	930	1,38	1,06	1,40

The amount of excavation of twin and single pipe system (3)

Twin pipe element: effect of the burial depth and protection distance

Twin pipe: coverage layer of 400 mm on main lines and branches, protection distance 100 mm

DN	Du	Cross sec. of element m3/m	Trenches [mm] h	a see Figure 2	e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	125	0,01	400	100	325	0,28	0,27	0,58
DN 40	160	0,02	400	100	360	0,32	0,30	0,62
DN 50	200	0,03	400	100	400	0,38	0,35	0,68
DN 65	225	0,04	400	100	425	0,41	0,37	0,72
DN 80	250	0,05	400	100	450	0,45	0,40	0,75
DN 100	315	0,08	400	100	515	0,55	0,47	0,84
DN 125	400	0,13	400	100	600	0,70	0,58	0,96
DN 150	500	0,20	400	100	700	0,90	0,70	1,10
DN 200	630	0,31	400	100	830	1,19	0,88	1,28

Twin pipe: coverage layer of 500 mm on main lines and branches, protection distance 100 mm

DN	Du	Cross sec. of element m3/m	Trenches [mm] h	a see Figure 2	e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	125	0,01	500	100	325	0,34	0,33	0,62
DN 40	160	0,02	500	100	360	0,39	0,37	0,66
DN 50	200	0,03	500	100	400	0,45	0,42	0,72
DN 65	225	0,04	500	100	425	0,49	0,45	0,76
DN 80	250	0,05	500	100	450	0,53	0,48	0,79
DN 100	315	0,08	500	100	515	0,64	0,56	0,88
DN 125	400	0,13	500	100	600	0,80	0,67	1,00
DN 150	500	0,20	500	100	700	1,01	0,82	1,14
DN 200	630	0,31	500	100	830	1,32	1,01	1,32

Twin pipe: coverage layer of 400 mm on main lines and branches, protection distance 150 mm

DN	Du	Cross sec. of element m3/m	Trenches [mm] h	a see Figure 2	e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	125	0,01	400	150	425	0,34	0,33	0,68
DN 40	160	0,02	400	150	460	0,39	0,37	0,72
DN 50	200	0,03	400	150	500	0,45	0,42	0,78
DN 65	225	0,04	400	150	525	0,49	0,45	0,82
DN 80	250	0,05	400	150	550	0,53	0,48	0,85
DN 100	315	0,08	400	150	615	0,63	0,56	0,94
DN 125	400	0,13	400	150	700	0,79	0,67	1,06
DN 150	500	0,20	400	150	800	1,00	0,80	1,20
DN 200	630	0,31	400	150	930	1,31	0,99	1,38

Twin pipe: coverage layer of 500 mm on main lines and branches, protection distance 150 mm

DN	Du	Cross sec. of element m3/m	Trenches [mm] h	a see Figure 2	e	Excavation m3/m	Back-filling m3/m	Ground surface m2/m
DN 25	125	0,01	500	150	425	0,41	0,40	0,72
DN 40	160	0,02	500	150	460	0,47	0,45	0,76
DN 50	200	0,03	500	150	500	0,53	0,50	0,82
DN 65	225	0,04	500	150	525	0,57	0,53	0,86
DN 80	250	0,05	500	150	550	0,61	0,56	0,89
DN 100	315	0,08	500	150	615	0,73	0,65	0,98
DN 125	400	0,13	500	150	700	0,90	0,77	1,10
DN 150	500	0,20	500	150	800	1,12	0,93	1,24
DN 200	630	0,31	500	150	930	1,45	1,13	1,42

Savings in heat loss

Comparison between a twin pipe element and horisontally installed single pipes.

Exchange rate:	1 USD = FIM 5.5	
Rate of interest	5	%
Calculation period	25	a
Price of energy	21,8	USD/MWh

	Twin pipe W/m	Single pipe W/m	Diffe-rence W/m	Savings %	Savings kWh/m/a	Savings USD/m/a	Savings USD/m
DN20	15,0	16,1	1,1	7 %	9,6	0,2	3
DN25	16,3	18,8	2,5	13 %	21,9	0,5	7
DN32	15,3	20,6	5,3	26 %	46,4	1,0	14
DN40	17,8	23,2	5,4	23 %	47,3	1,0	15
DN50	20,5	25,2	4,7	19 %	41,2	0,9	13
DN65	20,9	28,8	7,9	27 %	69,2	1,5	21
DN80	21,8	30,3	8,5	28 %	74,5	1,6	23
DN100	23,2	31,6	8,4	27 %	73,6	1,6	23
DN125	27,8	35,5	7,7	22 %	67,5	1,5	21
DN150	31,0	39,7	8,7	22 %	76,2	1,7	23
DN200	33,0	41,3	8,3	20 %	72,7	1,6	22

Heat loss calculations, yearly averages: supply water 90°C, return water 55°C, soil temperature +5°C.

Savings and benefits achievable with alternative techniques

Savings of twin pipe compared to horisontally installed single pipes

Exchange rate USD = FIM 5.5

Coverage layer (h) of 600 mm for horizontal single pipes and 450 mm for twin pipes, protective distance (a) 150 mm for single pipes, 100 mm for twin pipe

Grass surface

	Savings Material	Pipe work	Installation	Excavation	Top layer	Heat loss	Total	Saving	Average cost Single pipes horizontally	Average cost Twin pipe
	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	%	USD/m	USD/m
DN 20	8,00	5,60	1,00	6,90	3,20	2,40	27,10	29 %	93,8	66,70
DN 25	8,00	5,20	1,00	6,90	3,20	5,60	29,90	31 %	95,7	65,80
DN 32	8,00	3,80	1,00	7,50	3,20	11,80	35,30	36 %	98,2	62,90
DN 40	7,00	3,80	1,20	8,20	3,20	12,00	35,40	35 %	101,6	66,20
DN 50	7,40	3,60	1,20	9,00	3,00	10,40	34,60	30 %	113,5	78,90
DN 65	6,60	3,60	1,40	11,60	3,00	17,60	43,80	34 %	129,3	85,50
DN 80	6,20	3,20	1,40	10,70	3,00	18,80	43,30	29 %	150,5	107,20
DN 100	5,20	2,80	1,40	8,90	3,20	18,60	40,10	24 %	166,9	126,80
DN 125	1,00	2,40	1,60	5,00	2,60	17,20	29,80	14 %	206,5	176,70
DN 150	8,00	3,00	1,60	2,50	1,80	19,40	36,30	15 %	245,2	208,90
DN 200	1,00	3,60	1,60	1,50	3,00	18,40	29,10	9 %	309,3	280,20

Asphalt

	Savings Material	Pipe work	Installation	Excavation	Top layer	Heat loss	Total	Saving	Average cost Single pipes horizontally	Average cost Twin pipe
	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	%	USD/m	USD/m
DN 20	8,00	5,60	1,00	6,90	9,10	2,40	33,00	30 %	108,2	75,20
DN 25	8,00	5,20	1,00	6,90	9,10	5,60	35,80	32 %	110,4	74,60
DN 32	8,00	3,80	1,00	7,50	9,10	11,80	41,20	36 %	113,2	72,00
DN 40	7,00	3,80	1,20	8,20	9,10	12,00	41,30	35 %	116,9	75,60
DN 50	7,40	3,60	1,20	9,00	8,50	10,40	40,10	31 %	129,2	89,10
DN 65	6,60	3,60	1,40	11,60	8,50	17,60	49,30	34 %	145,7	96,40
DN 80	6,20	3,20	1,40	10,70	8,70	18,80	49,00	29 %	167,5	118,50
DN 100	5,20	2,80	1,40	8,90	9,10	18,60	46,00	25 %	184,8	138,80
DN 125	1,00	2,40	1,60	5,00	7,50	17,20	34,70	15 %	225,4	190,70
DN 150	8,00	3,00	1,60	2,50	5,50	19,40	40,00	15 %	265,2	225,20
DN 200	1,00	3,60	1,60	1,50	8,70	18,40	34,80	11 %	331,4	296,60

Savings of vertically installed single pipes compared to horizontally installed single pipes

Coverage layer (h) of 450 mm for vertical single pipes and 600 mm for horizontal single pipes, protective distance (a) of 150 mm for both types

Exchange rate USD = FIM 5.5

Grass surface

	Savings Material	Pipe work	Installation	Excavation	Top layer	Heat loss	Total	Saving	**Average cost Single pipes horizontally**	**Average cost Single pipes vertically**
	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	%	**USD/m**	**USD/m**
DN 20	-	-	0,95	2,80	1,90	-	5,65	6 %	**93,8**	**88,15**
DN 25	-	-	0,95	2,80	1,90	-	5,65	6 %	**95,7**	**90,05**
DN 32	-	-	0,95	3,00	1,95	-	5,90	6 %	**98,2**	**92,30**
DN 40	-	-	1,14	3,30	2,00	-	6,44	6 %	**101,6**	**95,16**
DN 50	-	-	1,14	3,90	2,10	-	7,14	6 %	**113,5**	**106,36**
DN 65	-	-	1,33	5,00	2,10	-	8,43	7 %	**129,3**	**120,87**
DN 80	-	-	1,33	4,40	2,20	-	7,93	5 %	**150,5**	**142,57**
DN 100	-	-	1,33	3,60	2,50	-	7,43	4 %	**166,9**	**159,47**
DN 125	-	-	1,52	2,70	2,60	-	6,82	3 %	**206,5**	**199,68**
DN 150	-	-	1,52	2,70	2,60	-	6,82	3 %	**245,2**	**238,38**
DN 200	-	-	1,52	0,70	3,30	-	5,52	2 %	**309,3**	**303,78**

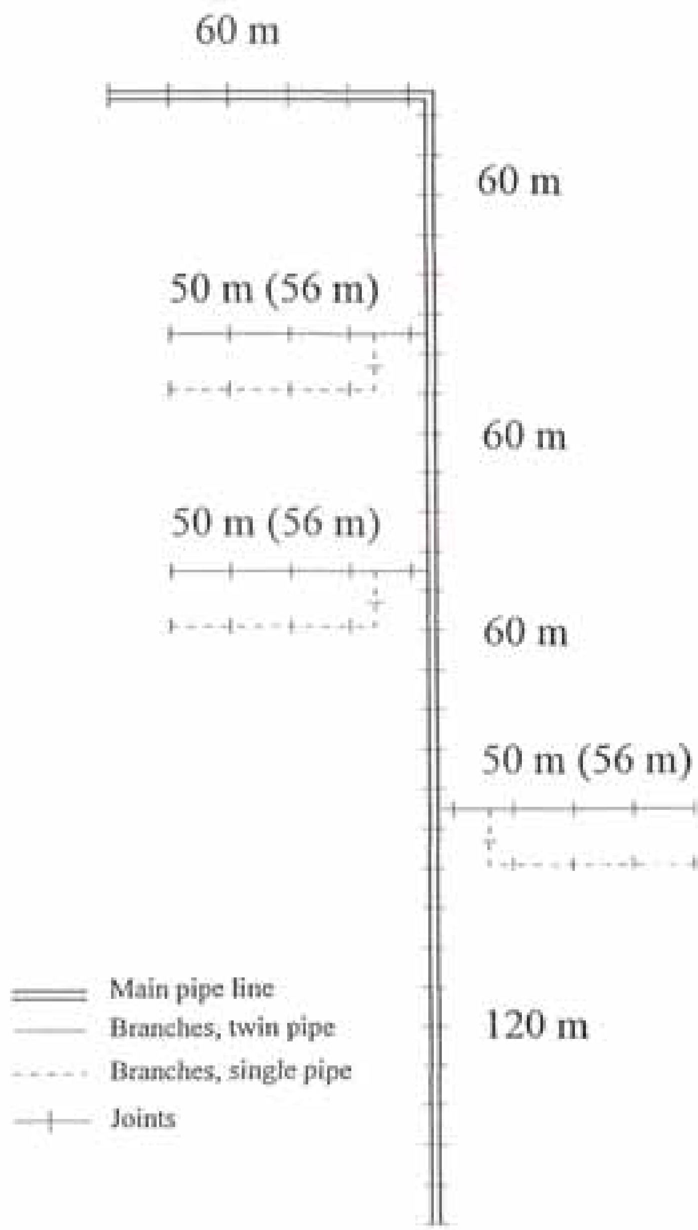
Asphalt

	Savings Material	Pipe work	Installation	Excavation	Top layer	Heat loss	Total	Saving	**Average cost Single pipes horizontally**	**Average cost Single pipes vertically**
	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	USD/m	%	**USD/m**	**USD/m**
DN 20	-	-	0,95	2,80	5,30	-	9,05	8 %	**108,2**	**99,15**
DN 25	-	-	0,95	2,80	5,30	-	9,05	8 %	**110,4**	**101,35**
DN 32	-	-	0,95	3,00	5,44	-	9,39	8 %	**113,2**	**103,81**
DN 40	-	-	1,14	3,30	5,60	-	10,04	9 %	**116,9**	**106,86**
DN 50	-	-	1,14	3,90	5,80	-	10,84	8 %	**129,2**	**118,36**
DN 65	-	-	1,33	5,00	6,00	-	12,33	8 %	**145,7**	**133,37**
DN 80	-	-	1,33	4,40	6,20	-	11,93	7 %	**167,5**	**155,57**
DN 100	-	-	1,33	3,60	7,00	-	11,93	6 %	**184,8**	**172,87**
DN 125	-	-	1,52	2,70	7,40	-	11,62	5 %	**225,4**	**213,78**
DN 150	-	-	1,52	2,70	7,80	-	12,02	5 %	**265,2**	**253,18**
DN 200	-	-	1,52	0,70	9,60	-	11,82	4 %	**331,4**	**319,58**

Savings and benefits achievable with twin pipe

The example network

Network used as an example for the comparison between single and twin pipe systems.



IEA District Heating and Cooling

New Ways of Installing District Heating Pipes

Published by
Netherlands Agency for Energy and the Environment
Mailing address: P.O. Box 17, 6130 AA Sittard, the Netherlands
Street address: Swentiboldstraat 21, Sittard
Telephone: +31 46 4202020
Telefax: +31 46 4528260
Internet: www.novem.org
Internet: www.iea-dhc.org

1999: T3.2

ISBN-90-5748-012-3