International Energy Agency

Programme of Research, Development and
Demonstration on District Heating and Cooling,
including the Integration of CHP

District Heating Network Operation

Part A: Servicing and Maintenance
Part B: Mobile Shut-Down Methods
and Repair Techniques

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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 1983 and 1999 under the auspices of the IEA 5 programs were carried out, Annexes I to V.

In May 1999 Annex VI has been startet up. The following countries co-operate in Annex VI: Canada, Denmark, Finland, Germany, Korea, the Netherlands, Norway, Sweden, United Kingdom and USA. The Executive Committee has set following priorities:

- Heat distribution
- Optimisation of a DH system by maximizing building system temperature differences
- Optimised DH systems using remote heat meter communication and control
- Simple models of operational optimisation
- Optimisation of cool thermal storage and distribution
- Absorption refrigeration with thermal (ice) storage
- Promotion and recognition of DHC/CHP benefits in greenhouse gas policy and trading programs
- District heating and cooling building connection handbook

NOVEM is acting as the Operating Agent for Annex VI.
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This report is part of the project "Heat Distribution" with the tasks

– Pipe laying in combination with horizontal drilling methods
– District heating network operation
  Supervision and maintenance
  Mobile methods of shutting down DH lines

The work on the task cold installation 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
· Paul Ramsak, The Netherlands
· Neville Martin, United Kingdom
· Heinz-Werner Hoffmann, Germany
· Manfred Klöpsch, Germany
· Ture Nordenswan, Sweden
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· 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. Nordenswan and Mr. Sirola for valuable contributions of material from Sweden and Finland.

Content

1 Summary

This report compiles experience from the operation of district heating pipelines over many years. In Part A important cost factors for the operation as well as the operating costs themselves are compared. Practical help for pipeline operation is given in Part B.

Part A is concerned with questions of servicing and maintenance. Information on the frequency of damage in modern district heating pipelines and the causes of damage are described and maintenance measures discussed. Effort and expenditure required for maintenance, deduced from practical operation over many years, are explained. International comparisons are presented for the most important components of the operating costs, heat losses, the energy demand for the pumps and water losses. These orientation values could be useful when making one's own operational comparisons.

Data on the costs for maintenance, repair and replacement of district heating pipes are available from a series of European statistics and comparisons. The reader can compare his own operating data with these values.

Part B of the report is purely practical. For routine work on district heating pipelines, for instance for new connections and repairs, helpful techniques which have been developed and proved effective at various locations are described. These are partly working methods, partly tools and even provisional aids. Separation techniques for pipelines without fittings are treated as well as tools and devices which have proved themselves particularly suitable for district-heating pipeline operations.

The report is not a manual for pipeline operation. Its intention is far more to make experiences of other supply companies available to those operators who are trying to reduce their running costs.

2 General Comments

The establishment of district heat supply has made a lot of progress in a number of countries. In individual cases it has almost reached its conclusion as all economically exploitable customers are already connected to the district heat supply, e.g. in Finland. The nearer one comes to saturation, the number of new constructions decreases and building is reduced finally to the connection of new buildings and to repair and renewal.

With the level of saturation of district heating systems, the cost awareness of the supply companies changes. At first, in the installation phase, because of the constant investment activities, efforts concentrate on reducing building costs. Later, the operating costs become more important, and these increase with the size of the system. Altogether the operating costs of heat distribution are known to be the largest cost block in the operating costs of the district heating system [1].

Operation follows two aims: first, it must guarantee to deliver to the customers according to the contract and without any disruptions. Secondly, the value of the distribution system must be maintained by servicing. The operating costs will depend mainly on the operational decisions:

- To what extent are maintenance and repair measures undertaken
- The length of intervals between servicing system components
- Decisions on repairs or replacement etc.

Reducing operating costs is a task for management. Minimising costs cannot be achieved by a single, limited measure, such as by making one procurement, but can only be obtained by a sum of individual measures. These could include reorganisation strategies for working processes, improvements in technical equipment in the plant, and training of employees.

The method of benchmarking has proved itself in detecting approaches for operational rationalisation. However, a comparison of characteristic values can only be carried out if the same boundary conditions are valid. This has been found to be very difficult when comparing different companies, who work under different economic conditions, are equipped with different technical systems and who have different types of supply tasks to carry out. In the case here, where international comparisons are to be made, there are still more difficulties.

The present task has the objective to summarise experiences from many years of operation of district heating networks and to make comparisons. In 2 parts, two different aspects of operation are treated.

Part A is concerned with questions of servicing and maintenance. Information on the frequency of damage is given, maintenance strategies explained and empirical values of operating costs presented.

Part B, on the other hand, is a purely practical manual. Help is given for the routine tasks which have to be carried out on a district heating network, i.e. for new connections, and repairs. This has been developed at various locations and has proved to be valuable. The subjects covered include working routines, tools and also provisional solutions.

For the experienced reader, not all the following descriptions will be new. They have been taken from everyday experience with district heating. The report will already have achieved its aim if it succeeds in bringing a few approaches towards saving costs to the attention of the reader or in pointing to several new ideas or aids, which simplify the daily tasks in network operation.

Part A: Servicing and Maintenance

3 Basic Information on Servicing and Maintenance

Measures taken in network operation are directed towards two different time horizons. In the long term maintenance has the task to protect the investments made; it must be planned over a long time period. In comparison to this, there are operational measures to control the network and to repair breakdowns. These require action to be taken at once and are therefore planned in the short term.

In a conscientiously managed company, the maintenance of the system proceeds in parallel to the planned renovation work. In connection with the repair of damage, it is difficult to decide whether a defect section of pipeline should be made operational again by means of a less expensive repair, or, anticipating the future, it may be more economic to replace the pipeline section, where the damage is found. This question will be treated in more detail later in Section 6.2, however, it should be added that there has to be an allowance made for individual opinions in this decision. It is possible to keep operating costs low for a short period by keeping the expenditure on maintenance low. In the long term, a deficit is built up which shows itself in higher rates of damage and lower availability of the system. Inevitably, this deficit must be cleared up at a later point in time. There are natural limits which do not allow the delayed maintenance to be postponed indefinitely, namely, there is the danger that breakdowns become so frequent that a normal operation can no longer be guaranteed.

The complex operating processes, which are to be evaluated here, must be compared with the help of suitable characteristics. Such a comparison is only correct when the system characteristics are used for identical conditions. Basic data from supply companies, which are needed in the comparison, suffer frequently because not all the required parameters have been collected or are not known.

A proved set of characteristics which have already been applied in the comparison of operating characteristics from supply companies from 8 countries, has been put together by the study committee “Heat transport and distribution“ from Euroheat & Power. This set of characteristics is listed and explained in Table 3-1. Orientation values from various sources for these characteristics are given in Section 6.

Further interesting suggestions for setting up a system of characteristics can be taken from the document [8], where aspects of maintenance are discussed and several flat-rate experiences are described.

Table 3-1: Characteristics for the comparison of operating procedures

Characteristic	Unit	Definition
System characteristics		
Average supply temperature	°C	Annual mean value
Average temperature difference	K	Mean temperature difference between supply and return flow over the year
Network volume	m^3/km	Network volume relative to the length of the supply pipelines (without house service connection pipelines)
Operating characteristics		
Heat losses	%	Amount fed into the network, minus heat quantity sold, divided by amount fed into the network
Energy demand of pumps	kWh/MWh	Demand for pump electricity, relative to heat fed into the network
Damage characteristics		(Definition of damage: Digging is inevitable or an interruption occurred.)
Frequency of damage	1/a*km	Number of damages per km trench length and year
Specific length renewed	m/a*km	Annual length of pipeline renewed per km pipeline
Feed water losses	m^3/ m^3*a	Annual amount of water to be fed in additionally relative to the network volume (without heat storage)
Economic characteristics		
Transport utilisation	MWh/km	Amount of heat fed into the network relative to the length of pipeline
Servicing- a. repair costs (may be handled seperately)	$/m*a	Servicing, maintenance and repair costs (without renewal) per pipeline length
Re-investments	$/m*a	Costs for renewal per pipeline length
Costs of operating management (Monitoring and control)	$/MW*a	Costs relative to connected load
Costs for the network operation (Servicing and maintenance)	$/MW*a	Costs relative to connected load
Costs for the station operation (Servicing and maintenance)	$/MW*a	Costs relative to connected load

4 Network Operation at Supply Companies

Various forms of organisation of the network operation can be found at supply companies. Large supply companies have their own personnel. This team carries out all work required for the operation of the network itself, sometimes even new building measures. The personnel take care of both the district heating pipeline as well as heat substations at the customer. Small supply companies often only have a few of their own personnel and perhaps allow all servicing and maintenance work to be undertaken by contracting companies. This is more favourable because personnel cannot always be fully employed and sometimes there is too much work to be undertaken by the limited staff. Between these two models all intermediary situations can occur at the companies.

In the care of supplier's service installations at the customers' the supply companies have to decide to what an extent it can provide a service. Sometimes the companies provide a comprehensive service, which could to some extent cover the care of domestic systems, or even include them absolutely. The costs for servicing domestic house systems are charged to the customer. This assumes that the boundary between distribution network and domestic system is clearly defined at least as far as the question of ownership is concerned. The extent of the service has a considerable influence on the operational costs of the supply company.

In spite of reducing personnel, outsourcing and lean management, a supply company should ensure that all necessary know-how stays in his own house. Reliable information on the condition of the systems and a general picture of the state and development of damage are preconditions for a cost-optimised maintenance. This information is to be prepared by electronic data processing and made available to the personnel. Electronic data processing allows the analysis of damage according to type of damage, for instance, pipe systems, age structures, breakdown of particular components, localised problems.

Today, most of the pipelines, which have to be cared for by works personnel, consist of plastic jacket pipelines. Only these are relevant in this report. Internationally the networks are equipped with the same pipe material and are only different in their design. In Finland only thermally pre-stressed preinsulated pipes are installed, at other places they are to some extent installed cold.

National differences are found in the operating temperatures, which is relevant for the static stresses of the steel pipeline and for the thermal load on the PUR-foam. In Scandinavia the operating temperatures are normally lower than in Central Europe, so that pipelines are less stressed under the same conditions. These differences will not be taken into account within the framework of the present report, where only expenditures for the operation will be considered and these will be simplified to be independent of the operating temperature. It can anyway be assumed that the pipeline operation will be suitably adapted to the load conditions.

One influence on the operating expense is pipeline monitoring. Many supply companies believe that with network monitoring they are better equipped against operational disturbances since they can locate leaks more quickly. This estimation goes against the practical experiences in Finland, where the costs of such systems are considered to be too high in comparison to the benefits. See Section 5.2 for more details.

5 Frequency of Damage, Availability

In a district heat network some work must be carried out which can be planned in advance but other tasks require immediate attention, usually larger leaks. These must be repaired at once, otherwise the supply operation cannot be continued. An emergency service is organised for such breakdowns. This emergency service can be carried out by employees of the supply company or, for small systems, by external companies.

A well organised emergency service can repair leaks within a few hours. From experience even repairs on large pipelines do not cause breaks in supply of more than 4 hours. For district heat networks one can therefore assume as an approximation: The availability of district heat networks is ca. 100 %.

A more exact investigation of standstills was carried out in Finland. The availability of Finish district heat networks was [4, 14]:

in 1999	99.993 %
in 2000	99.991 %

The standstill period per customer was an average of about 0.8 hour per year.

In addition, the Finish statistics presented impressively the ease of repair of preinsulated pipes in comparison to old pipeline systems. Whereas damage to a plastic jacket pipeline causes an average supply interruption of 4 hours, for a pipeline in a concrete duct it lasts 10 hours.

Critical damage situations for the works operation are often caused by technically inferior pipelines or components. Such developments of damage are of no interest for this report. These damages usually have more particular causes as they are, for instance, concerned with very special building techniques, refer to technically out-of-date systems or occur to components which are particularly susceptible to damage. In the following, practically only plastic jacket pipelines will be mentioned as they present the international state-of-the-art and are almost exclusively applied in new constructions today.

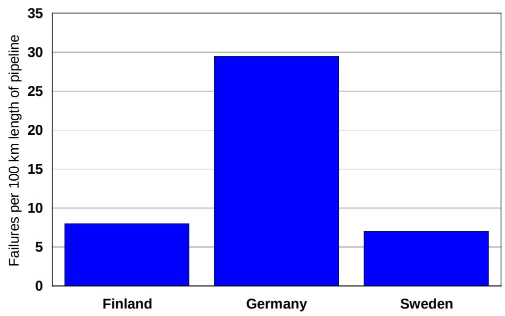


Fig. 5-1: Rate of damage for preinsulated pipes incl. damages from external causes

5.1 Rate of damage

Today's experience with preinsulated pipes allows two comments to be made to summarise the situation.

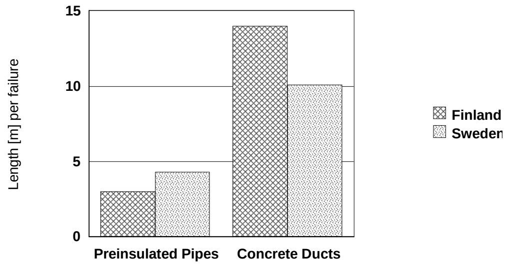
1. Newer networks of modern preinsulated pipes and without shaft installations have a lower rate of damage [3, 18].
2. Preinsulated pipes require only a low effort for maintenance as well as low repair costs, see Section 8.

Generally in district heat networks the damage rate is calculated to be about 10 to 20 cases per 100 km pipeline [1, 12]. This is a general value which is valid for historically developed networks, i.e. for networks with pipelines of different construction and a pipeline inventory with sections of different ages.

Statistical data are available for modern preinsulated pipes and are presented in Figure 5-1 [4, 5, 23, 27]. These data also include damages which were caused by external effects. As a result of the intensive development in the field of sleeve techniques, in the recent past, new preinsulated pipes have been allotted an even lower rate of damage. A survey how failure rate changes with lifetime of the pipeline will be given in chapter 6, see figure 6-1.

Preinsulated pipes require little repair. They are also watertight along their length so that in case of leaks only a short longitudinal section is affected. The Swedish and Finish statistics show the lengths of repaired sections preinsulated pipelines and in concrete ducts [4, 23], see Figure 5-2.

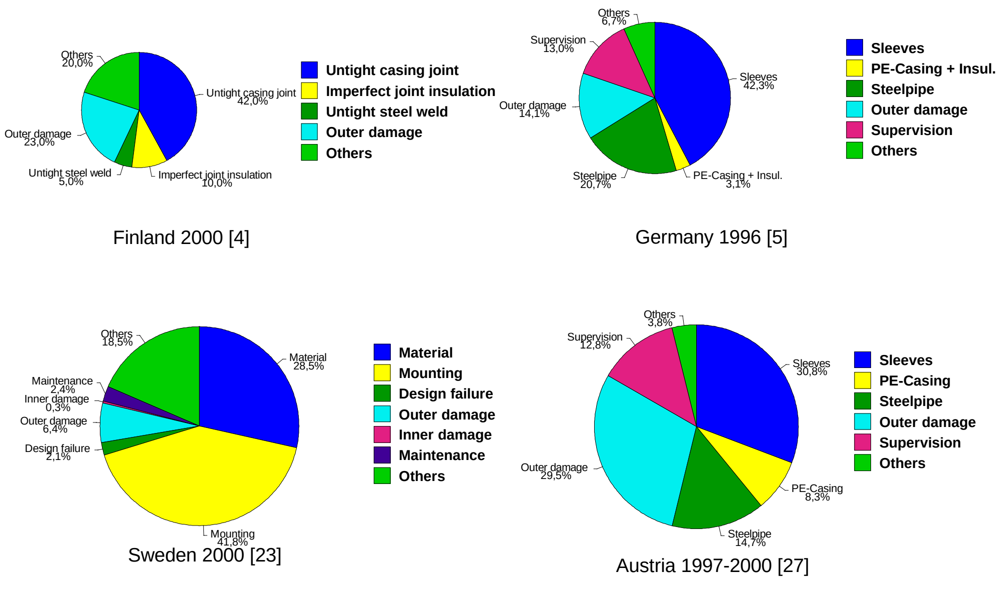
Fig. 5-2: Length of pipe renewed during reparation



5.2 Causes of damages to preinsulated pipes

Damage to preinsulated pipes occurs mainly at the sleeve connections of the jacket pipe. However, there are other areas where damage is found, e.g. the welded seam of the steel pipe, the insulating foam and the monitoring system. Comparative numbers from 4 countries are shown in Figure 5-3 for each country.

Fig. 5-3: Causes of damages



Shrink sleeves are rightly considered by experts to be more reliable than clutch sleeves. This can be proved by figures from a comparison carried out in Germany. Clutch sleeves had three times as many damages as shrink sleeves [31]. (It has to be mentioned that there are some uncertainties about this relation as it is unknown how many shrink sleeves and how many clutch sleeves are installed in German DH networks.)

5.3 Network surveillance

In order to detect damages to the district heating network and to be able to locate it as quickly as possible, preinsulated pipes are usually fitted with a surveillance system. There are 4 systems on the market today:

System Brandes
European Monitoring System (Nordic System)
System T 60/1 (HDW)
System AB-Isotronic

The 4 systems compete one with another. They work to some extent according to different measuring principles. System 2 is preferred in Denmark and Sweden.

Network surveillance is for the operational control of the pipeline for the occurrence of water. The fact that damages can be detected early so that its extent can be kept low is often regarded as particularly advantageous. The damage statistics carried out over many years by MVV Mannheim, Germany prove that with the sensitive monitoring system used there, 83 % of damages can be detected in the first 5 years after commissioning. The repair costs can then be claimed within the framework of the warranty provided by the pipe-building company.
The cost-benefit-ratio of continuous monitoring of the pipeline has been controversially

discussed over a long period of time. The advantages of pipeline monitoring are well-known, in particular the early detection of construction faults possibly still in the guarantee period and the operational advantages. Disadvantages are the high damage rate to the monitoring system, see Figure 5-3 showing the diagrams for Germany and Austria, together with the procurement costs which are often played down. They are not negligible as shown in [18]. It seems that there is a strong cost-benefit-ratio argument against these systems. Safety considerations of the pipeline operation, according to which the pipeline monitoring can be a saving aid in the case of breakdowns, are difficult to assign a value to, so will not be taken into account here.

Up to now, this discussion has been consequently decided in Finland. There, in connection with consistent quality monitoring, warning wire systems are only installed in the most exceptional cases. Small and medium-sized pipelines up to DN 250 are not fitted with a leak monitor. (Another support for this decision is given when one looks at the new German damage statistics [31] and compares how damages to the pipeline are determined; only about 60 % of damages which occur were detected with the aid of the electrical pipeline monitoring system. And it seems that leak detection works better in smaller pipelines than in bigger ones.)

In Sweden installation of a surveillance system is usual. 67 % of the damages are recognized by the surveillance systems.

6 Maintenance Strategies

6.1 Theory

The execution of a maintenance measure can be divided into 3 working steps [26]:

1. Planning and preparation
2. Execution
3. Evaluation of the maintenance measure carried out

The planning of the maintenance measure must be closely connected to the evaluation of the maintenance measure carried out. Both steps are often summarised by the term "Preparation of maintenance work". The tasks of work preparation are listed in Table 6-1.

Table 6-1: Tasks in preparation of maintenance work [7]

Main Tasks	Tasks
Preparation of maintenance work	- Strategy planning - Personnel planning - Planning of machinery - Planning of material - Budgetary planning - Drawing up a work plan - Cost planning - Advice to other sectors
Maintenance planning	- Maintenance programme planning - Schedule and capacity planning - Planning of quantities
Maintenance control	- Placing the order - Controlling the order
Maintenance analysis	- Analysis of deviations from order - Analysis of weak spots

In addition to the time schedule and capacity planning, the main aim of maintenance planning is the formulation of the maintenance requirement. This requirement depends on the strategy selected by the supply company.

The following strategies are possible for the maintenance of supply pipelines, see also Table 6-2.

- Breakdown strategy
  Operational measures are only applied when a breakdown has been determined. No systematic tasks are carried out. – This procedure saves costs at the beginning, but in the long term leads to increasing rates of damage and a generally superannuated district heat network.

- Preventive strategy
  The installation components of the distribution system are changed after a fixed period of time, which is decided according to the average lifetime of the components. Here it can happen that even components which still have a notable remaining service life are replaced. The pipeline is always in a good and reliable condition; however, the expense is high. This strategy is seldom found at the supply companies.

- Inspection strategy
  The inspection strategy adapts the effort to the requirement. The operational measures are ascertained according to the local conditions, to the frequency of damage and expected development as well as to the results of the damage.

The inspection strategy requires that the condition of all pipeline sections of the district heat network is known in detail and documented. From statistics on damage, the technical details under which comparable damage has occurred must be known.

- approximately the same ground and ground water conditions are found,

it can be assumed that the average technical useful life is essentially a function of time.

Table 6-2: Strategies for the maintenance of district heating systems [7, 15]

Strategy	Action	Results
Breakdown strategy	only repairs	- increasing rates of damage - sinking quality - for the moment few repairs
Preventive strategy	renewal at fixed intervals of time	- few repairs - higher standard - higher cost
Inspection strategy	renewal according to condition / renovation	- limited breakdowns - consideration of local damage - effort adapted to conditions

If the damage situation in companies is carefully analysed, valuable conclusions can be drawn. It is important that the collection of such data is so structured right from the beginning that later the desired statements can be deduced. There are already various proposals for data collection, in particular from the national expert associations, see for instance [12], unfortunately, no standard concept. Damage must be summarised in groups of damage. Such groups should be pipeline systems, laying technique, certain components, trade names or materials, assembly techniques (types of sleeves), installation situations etc.

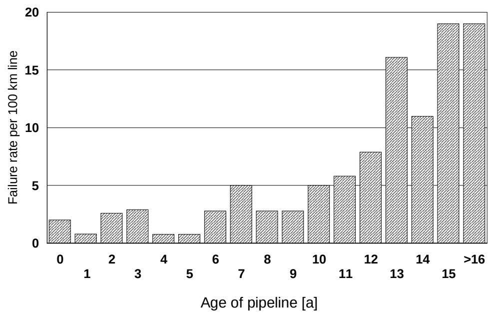
The rate of damage to district heat pipelines increases dramatically with age, see Figure 6-1, top. For this reason it is justified fixing an average technical useful life for a pipeline. This is not unequivocally defined, but, based on experiences over many years, it is possible to estimate this average technical useful life. Investigations of old pipelines are a good help [25]. Similar information is given by Figure 6-1, bottom. Additionally it shows an elevated failure rate for 20 years old pipelines. At the time of construction there existed problems with the quality of joints.

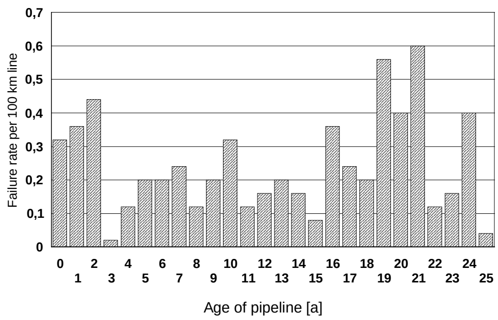
Under the conditions that

- similar pipe systems are under consideration,
- roughly the same diameters are being considered,
- the same building techniques were applied (sleeve technique, materials) and

The average technical useful life must be determined for the situation at the companies from all the values known from experience and in particular according to an evaluation of carefully worked out damage statistics.

Fig. 6-1: Rate of damage of district heating pipelines as a function of age
top: average on total Finnish networks [21]
bottom: preinsulated pipe systems, Sweden [23]





The sections of pipeline which are actually replaced do not usually show the same average technical useful life. Frequently pipelines must be moved before they reach the end of their useful life as a result of other building measures or they are replaced because of increases in capacity. On the other hand, there are pipelines which well exceed their expected useful life, as a result of a more favourable laying or a particularly high-quality construction. From experience it can be said that the life of replaced pipelines has a normal distribution, as shown in Figure 6-2. Figure 6-2 also makes it clear that pipelines should not be replaced just because they have reached a certain age. This can lead to unnecessary costs.

Fig. 6-2: Age distribution of replaced pipelines

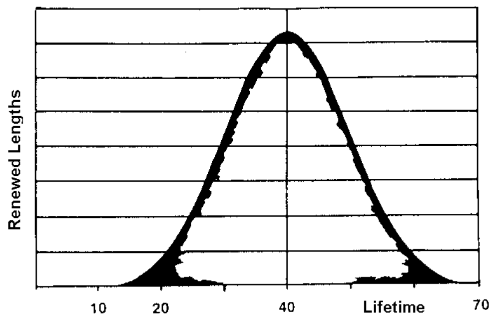
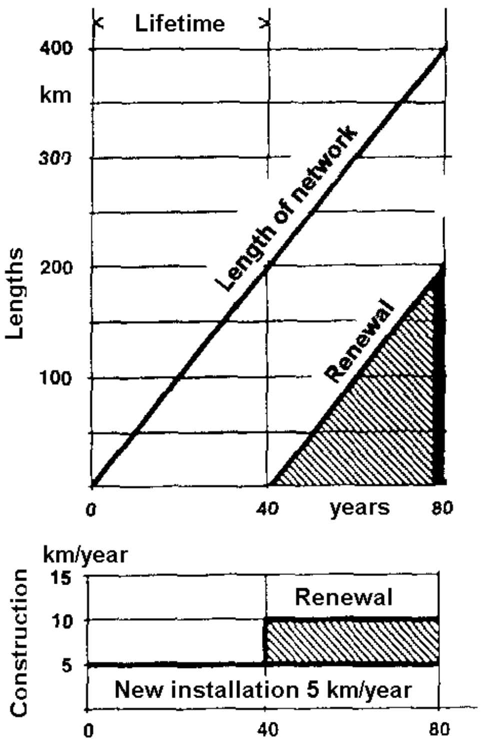


Fig. 6-3: Diagram of continuous network extension and the replacement required in theory



Theoretically, for the determination of the annual demand for replacement, it may be said that when the average technical useful life at the company is correctly determined, for the company with a network that has grown over many years, there develops a requirement for replacement after a certain moment in time. When seen purely statistically, this requirement for replacement is only dependent on the average technical useful life and not on the topical occurrences of damage. (That the replacement planning of the company is nevertheless dependent on the topical development of damage is discussed in Section 6.2.)

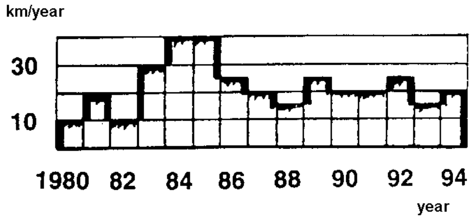
This is presented in the diagram in Figure 6-3. The graph is valid for a pipeline system which has an average technical useful life of 40 years. The diagram shows how the stock of pipelines increases linearly with time for a constant rate of extension. In the case of responsible works managers, replacement must start after 40 years, also with constant annual building rate. The replacements increase parallel to the stock.

6.2 Operational practice, experiences

Whereas the necessity for a systematic, replacement planned over a long-term can be theoretically convincingly confirmed, nevertheless the daily business of the network operation must be organised pragmatically. In order to achieve a rational method of working for the personnel, short term regular tasks have to be carried out in combination with maintenance measures required in the long-term.

On the other hand, the way in which the actual annual replacement rate in a supply company is normally regulated is shown in Figure 6-4. The adaptation of the annual replacement rate is needed to avoid load peaks both for the employees and also for external companies. In addition, consideration must be given to public interests as well as to the financial strength of the company.
The exchange of old components or the unreliable pipe systems is always planned in the long-term. However, the systematic replacement of preinsulated pipes is not practised anywhere today. Even in countries where these pipe systems were introduced right at the beginning, there is still no demand for a

Fig. 6-4: Diagram of the annual rate for the replacement of pipelines



complete exchange. After more than 30 years, these pipelines have not yet reached the end of their lifetimes. Results of tests indicate that even older designs of these pipelines still have considerable lifetime reserves [25]. In addition, the systems have undergone considerable quality improvements from their introduction up to the present day.

Operational decisions on maintenance/replacement should be made on the basis of an analysis of the damage statistics. From the information gained on typical cases of damage, fundamental decisions for the long-term planning of replacement can be deduced, in particular:

- Which groups of pipeline systems, sleeves, fittings possibly from certain manufacturing periods or nominal diameters are to be replaced after how long a useful life?
- Are there any installation situations or geological conditions which make special measures necessary?
- What modern techniques are to be used for the replacement?

7 Personnel and Material Requirements

Every supply company has an operating concept, in which the maintenance philosophy and personnel resources are harmonised. The maintenance is adapted to the works equipment, security of supply, extent of the service to the customer etc. The number of employees is fixed so that the necessary work can be undertaken. The works management have a problem when determining the maintenance effort: security of supply and customer-friendly service speak for extensive maintenance, whereas the costs demand a minimisation of the effort.

Different practices have grown up at supply companies as a result of their independent development. In Germany these differences were taken as the reason to bring together comparative values showing what maintenance effort is normal at the companies for similar performances. A group of interested companies compared their data.

The investigation brought extreme differences to light. For instance, there are supply companies, which inspect their district heating chambers once a month whereas others consider once a year sufficient. The most important results from this exchange of experiences are presented in Table 7-1, whereby, in addition to an average value, low and high comparative values are given. However, untypical extreme values have been omitted.

At the utilities it has turned out practical to adjust maintenance expenditures to the importance of the lines. Often 3 categories are used, one for important lines, one for standard lines and one for small lines of the lower distribution.

Normally these maintenance tasks are undertaken by 2 technicians, who work together and are equipped with one works vehicle. The work cannot be carried out by only one individual as this is forbidden for safety reasons.

Table 7-1: Typical time required for maintenance measures in Germany [2, 28]

Object of the Maintenance	Unit	Low	Average	High	Least No. of Times per Year
1. Pipelines					
1.1 Plastic jacket pipes	h/(km*a)	0.5	3		0.5 - 2
1.2 Concrete ducts	h/(km*a)		1		
1.3 Ducts that can be patrolled	h/(km*a)	1	10	20	1 - 12
1.4 Overhead pipelines	h/(km*a)	1	10	20	1 - 12
1.5 Steel jacket pipes	h/(km*a)	0.5	3		
2. Chambers	h/chamber	0.5	3	3.5	1 x (1 - 3)
3. Fittings for installation in ground	h/fitting				1 x (0.5 - 2)
4. Bridge installations	h/bridge	1	4	8	1 x (0.2 - 4)
5. House service stations	h/station	0.5	1.5	2.5	1 x
6. Exchange of heat meters					
6.1 Q_N ? ? 10 m³/h	h/meter	0.5	1.5		
6.2 Q_N > 10 m³/h	h/meter	0.5	2	2.5	

8 Operating Expenses, Costs

The operating expenses for heat distribution consist on the one hand of continuous expenses for machinery materials and on the other hand mainly for staff costs for the running operations. Th most important components of the first category are heat losses, electricity for pumps and water losses. The second category includes expenses for operating and controlling the system, for the maintenance (servicing + repair) and (poss.) for maintenance of the heat transfer stations. In the following, the values from experience are given.

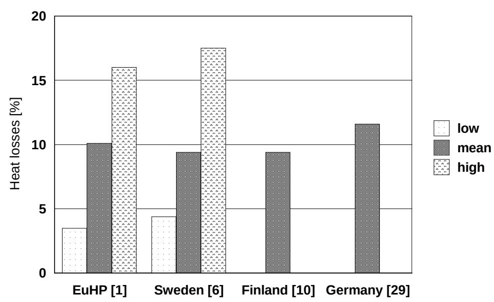
Replacement of parts of the district heat network should come under the heading of investments and not operation.

8.1 Heat losses, energy demand for pumps, water losses

In the breakdown of network costs, heat losses take up a large block. Costs for circulating water are considerably lower and, in third place, follow the costs for refilling to compensate for unavoidable water losses. However, even this relatively small amount justifies efforts to make savings, since, in a large supply company, it can amount to about 10^6 \$/a.

Yearly averages for heat losses in district heat networks operated with water are about 10 % of the heat amount fed-in. Figure 8-1 presents comparative values.

Fig. 8-1: Heat losses in district heating networks [1, 6, 10, 29]

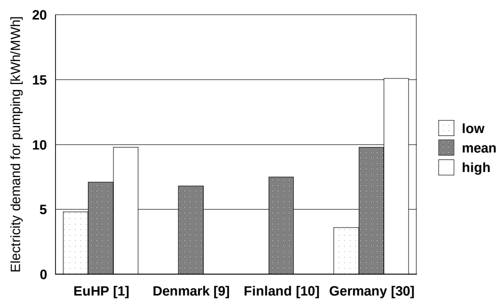


The average values according to EuHP and Germany are higher than the Swedish average value because these numbers are obtained from heating networks which have developed over decades and include many old pipelines, for which higher heat losses must be expected. Besides operating temperatures are generally higher in Germany.

The heat losses considered here follow the definition usually used by the branch. They do not take into account the energy fed into the system over the pumps, which is a result of frictional losses also lead to heat. The physical losses are therefore somewhat higher by about 1 %.

The energy demand of the pumps is normally represented relative to the heat quantity fed into the network. On average, this figure is between 6 to 10 kWh/MWh meaning that, energetically, 0.6 to 1 % of the energy content is fed to the district heat network in the form of electrical energy.

Fig. 8-2: Energy demand of pumps [1, 9, 10, 30]

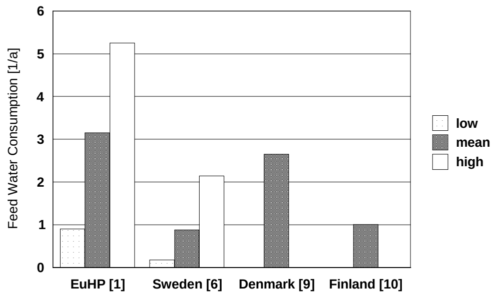


In this comparison of data, it should be noted that Finish companies give a higher utilisation period to describe their systems. This must lead to higher electricity demand for the pumps. The Danish figures refer to 50 companies with a minimum power of 25 MW. The German data could not be obtained by means of data collection across the branch, but presents the values given by 10 large supply companies.

In the design of the pumps, and hence in the hydraulic optimisation of the systems, long-term considerations should also be taken into account. A sufficiently large dimensioning of the pipelines reduces the costs for water circulation. In particular supply companies which do not have their own power generation and have to buy electrical energy, are known to be trying consequently to obtain a lower power demand for water circulation.

Water losses in district heat networks are presented as annual water quantities used to fill up the system relative to the network volume. Using network volumes, heat storage is not taken into account, as this only occurs stochastically and with the large water content would lead to implausible comparative numbers. However, this definition of water losses is not correct, as undesirable water losses through leakage are only part of the quantity of water added to the system. The other part includes water needed to fill new systems for instance. The characteristic of water losses, as also shown in Figure 8-3, demonstrates clearly the number of times the network volume has to be fed into the system per year.

Fig. 8-3: Feed water consumption in district heating networks [1, 6, 9, 10]



The average values for water losses are 1 to 3-times the network volume. In practice, the values vary considerably. They are often higher when the district heat network includes components of a poorer quality, which are in this case perhaps the objectives of a targeted maintenance programme. Very low water losses are generally considered as the criterion for a qualitatively high-value network. Very high water losses were reported [1] in one case. They amounted to 14.7 per year. Nevertheless, the network continued to operate.

The definition of water losses includes water quantities which are not proper losses but amounts which are needed to fill customers systems. In particular this water demand for filling must be taken into account when assessing a plant where customer systems are connected directly.

Efforts to reduce water losses are particularly worthwhile, since expensive, prepared water is lost and has to be replaced. Usually this is completely desalinated water. The specific costs of water preparation are considerably higher in small systems than in large systems at power stations.

8.2 Costs of operation of network and stations

It is well-known that it is difficult to compare costs across country borders. This problem was found when comparing building costs. Often labour is paid for at completely different prices in the individual countries. In addition, there are wide statistical scatter areas which are obligatory particularly when considering costs. Nevertheless, when numbers are given here, the reader is asked to try to explain the contradictions in the situation in his own company by considering differences in the boundary conditions.

The following comparative values are formulated using proved characteristics. The characteristics follow the definition in Table 3-1.

Within the framework of this task, only the costs of maintenance are considered, i.e. only repair costs. In Germany an extensive investigation on this subject was carried out at the supply companies. However, there were great difficulties because the supply companies set different boundaries between repair and new construction (new investment). Whereas the exchange of a few metres is often seen as replacement (investment) and not as repair, in other cases the limit is set at 100 metres or more. Comparison of figures is strongly affected by this and more problems of book-keeping. Unfortunately, these effects cannot be eliminated in the following cost comparison.

The maintenance of the district heat network takes place normally together with the maintenance of house substations. Often as a practical value for splitting the total costs between the two fields a ratio of about 1:1 is given. The international comparison between 8 large towns in [1] gives an average value of 1.4, that is a predominance for the costs of the network operation, see Figure 8-4. However, in one case it happened that the expense for the substations has a stark predominance, i.e. for Oslo, Norway where a ratio of 1:3 is given.

Fig. 8-4: Distribution of maintenance costs of district heat between network control, network operation and substation operation [1]

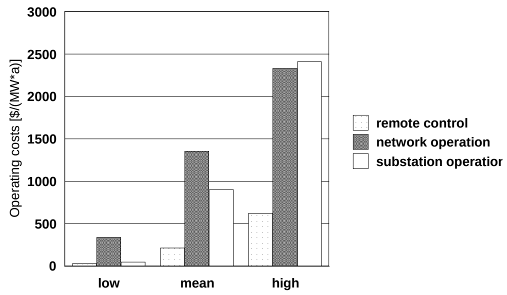
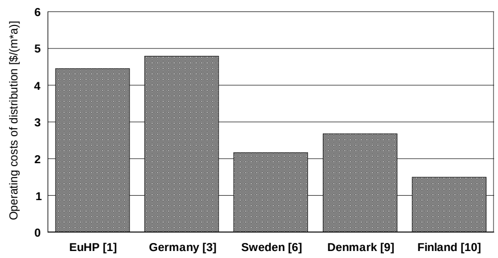


Figure 8-4 shows the characteristics of the operating costs defined by annual costs relative to the connected load. This definition is favourable as it smoothes out the effect of the density of housing. In highly-populated areas, as a result of the difficulties, the repair and operating costs are higher than in areas with less density of housing, whereas at the same time the connection loads for the connected objects are higher.
As an alternative, the operating costs are often quoted relative to the pipeline length. This definition is used in the following consideration as more national statistics are available in this form and cannot be recalculated here. Figure 8-5 reproduces a comparison of operating costs based on an EuHP-enquiry and 4 national statistics. The EuHP-data refer to 8 large central European towns and cities.

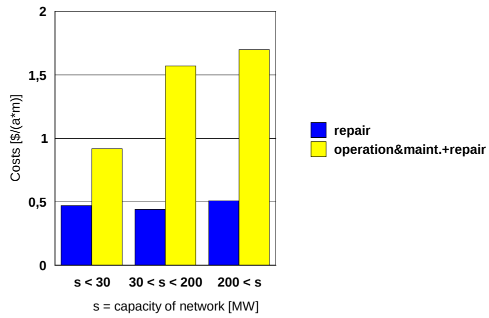
Fig. 8-5: Comparison of maintenance costs of district heat distribution in Central and Northern Europe



For the EuHP-data and for Germany the diagram shows annual maintenance costs of 4.5 $ per metre pipeline whereas, for the Northern European area, costs of about 2 $/m, only half so high, are quoted. Probably the difference can be explained by the fact that the values from EuHP and for Germany refer exclusively to very densely built towns, whereas in the Northern European areas mostly simpler environs and building conditions are found. It is known that in the building costs for new lines there are also similar distinct differences between Germany and Scandinavia.

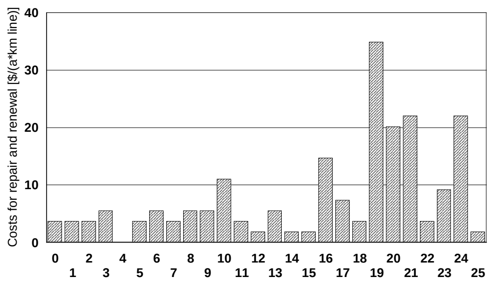
Maintenance costs for Finland, shown on the right in Figure 8-5, can be broken down still further, as the Finish statistics show separately the repair costs as part of the maintenance costs. Figure 8-6 presents the repair costs and the maintenance costs. The diagram is arranged so that the district heat networks are separated into 3 size categories. On average, the repair costs form 30 to 50 % of the maintenance costs.

Fig. 8-6: Repair costs compared to maintenance costs in Finland 2000 [10]



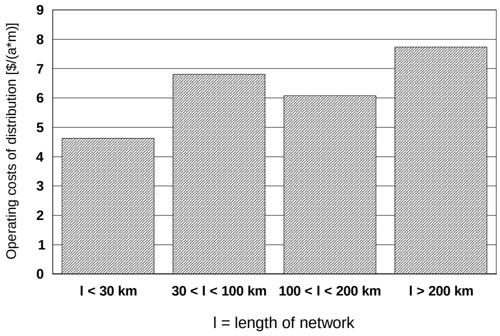
The costs for repair and replacement are very low for new pipelines and increase with the age of the pipeline. Swedish statistics, see Fig. 8-7, give an impression of the cost increases with age of the pipeline. (The graph refers to the same network as shown in Fig. 6-1)

Fig. 8-7: Costs of repair and replacement of preinsulated pipes as a function of age



Surveys on maintenance costs according to the size of the network clearly indicate that large district heat networks require higher maintenance costs than smaller ones. This is shown in Figure 8-8 and will be discussed in the following using the values from Germany.

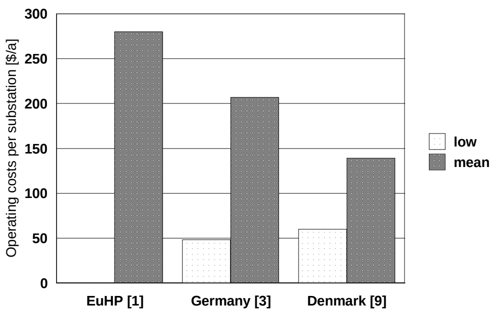
Fig. 8-8: Maintenance costs of district heat networks of different sizes in Germany [3]



This result, which appears at first to be surprising, can be explained by the age structure of the networks. Since district heat networks have mostly been constructed and consolidated over a longer period, large networks have a higher proportion of older pipelines and components. These cause the increased expenditure on maintenance. On the other hand, small networks have a lower average age.

Comparative values of maintenance costs for house substations are reproduced in Figure 8-9. As could already be seen in Figure 8-4, there is a particularly high variation width between the categories low and high costs, as the supply companies offer their customers very different services according to the company's philosophy. Some companies understand their services to include the care of domestic systems and this automatically leads to higher operating costs if there is no separate billing for this service.

Fig. 8-9: Comparison of the maintenance costs for house substations

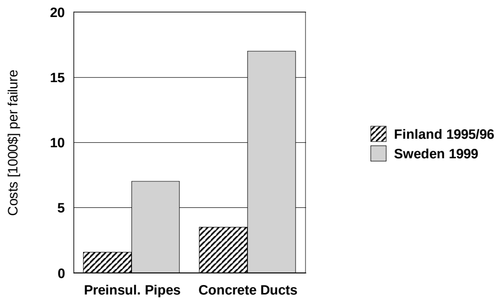


The diagram shows lower average costs for Denmark. This seems to reflect the fact that in connection with the low operating temperature very simple cost-effective stations have always been installed, mostly for direct connections.

8.3 Repair costs, replacement

The ease-of-repair of new pipeline systems is clearly shown by the repair costs for a case of damage. Finish and Swedish statistics have given comparative values, see Figure 8-10. Here the costs for one repair to a plastic jacket pipeline and in comparison to a pipeline in a concrete duct are presented. The low costs for the plastic jacket pipeline are the result of the longitudinal imperviousness of the system and from the considerably reduced expenses for underground engineering costs. – May be the explanation for the low Finish costs is that pipelines are mostly not laid under roads but under sidewalks and green areas. Realizing the high Swedish value for concrete ducts it must be added that concrete ducts in general have bigger dimensions.

Fig. 8-10: Comparison of repair costs for damages to preinsulated pipes and to pipelines installed in concrete ducts [4, 21, 23]



The systematic replacement of plastic jacket pipelines is not yet necessary today. However, old pipelines (others than preinsulated systems) are already being exchanged for new ones. This replacement rate in Sweden is estimated to be about 1.5 % of the total length of the network [6]. In Finland it is less than 0.5 %.

8.4 Summary of costs

In addition to favourable building costs, modern plastic jacket pipe systems also offer the supply companies considerable advantages in operation. Whereas conventional systems were at one time equipped with shaft installations and numerous fittings, these are no longer necessary in pipeline building today and, as a result, considerable running costs are also saved. Shaft installations and fittings lead to high maintenance costs.

Furthermore, thermally insulated pipelines reduce the heat losses. The PUR-foam offers a very good thermal insulation which can be adapted to the economic optimum by choosing the corresponding insulating range.

Preinsulated pipes are longitudinally impervious. In case of damage water spreads out only slowly in the longitudinal direction so that only short pipe sections have to be exchanged in case of repairs.

Considering monitoring the pipeline, 2 strategies have developed. In most cases the pipeline is fitted with a warning wire system, whereby either all pipelines up to the customer or only the main pipeline are monitored. In Finland, smaller and average and in many cases even bigger pipelines are not monitored. After more than 30-years experience added to an appropriate quality control, one believes that preinsulated pipes can be installed in such a reliable way that the benefits of monitoring are lower than the costs.

Concrete benchmarks for the operating costs which a company should aim at will not be given here. The boundary conditions at the supply companies are too different. As an alternative, practical values have been described and each company must develop his own targets taking into account his own particular situation.

Finally, in the last Section of this report is an extensive bibliography from where additional information can be obtained.

9 Guidelines, Typical Values

In supply companies efforts can be started with the aim of obtaining short-term cost reductions. This is possible by simply reducing the quality control at the site, by lengthening the maintenance cycles or by following a maintenance concept which is only oriented to damage. The results would of necessity be increased costs in the following years. Such a strategy in general goes against the operational management of the supply companies, as they usually secure their system durability well in advance.

A conscientious maintenance strategy must aim to [8],

- Achieve a low rate of replacement with fair maintenance costs,
- Install only reliable pipe systems with long useful life,
- Pay attention to careful building construction so that influences from the building phase do not shorten the life-time,
- Use measures to lengthen the lifetime (leak monitoring).

The reduction of operating costs, so far as they are achieved by measures which are immediately effective (frequency of inspections, servicing intervals), also lead to cost reductions at the supply companies which are only effective in the short-term. Beyond this it is also possible to achieve reductions over the medium and long-term (water losses, energy for pumps).
Data for orientation on the necessary time required for important maintenance work have already been described in Section 7. Additional characteristics of the operational expenses are summarised in Table 9-1, where a range for each value is given.

Table 9-1: Orientation values of the characteristics of district heat operation

Characteristic	unit	low	average	high
Characteristics of the System				
Average Flow Temperature	°C	Attainable and economic 85 to 95		
Average Temperature Difference	K	40		
Operating Characteristics				
Heat Losses	%	4	8	16
Energy Demand of Pumps	kWh/MWh	5	7	10
Damage Characteristics				
Frequency of Damage	1/a*100 km	1	10	
Feed Water	1/ *a	1	1.5	6
Economic Characteristics				
Servicing and Repair Costs	$/km	500	3500	9000
Reinvestments	$/km	400		9000
Operating Costs (Control and Monitoring)	$/MW	30	200	600
Costs for Network Operation (Servicing and Maintenance)	$/km	500	1500	2500
Costs for Substation Operation (Servicing and Maintenance)	$/km	50	1000	2500

Part B: Mobile Shut-Down Methods and Repair Techniques

10 Basic Information on Shut-Down and Repairs

Whereas 20 years ago, district heating pipelines were always laid on a defined gradient and shut-down of segments was foreseen to be carried out at regular intervals, today, at least in the case of small and medium-sized pipelines, the so-called flat-laying is practised. This is characterised by the fact that pipelines with constant coverage are laid parallel to the surface, i.e. without a defined gradient. Furthermore, as far as possible, the shut-down of segments has been almost completely done away with. Venting and draining fittings as well as shafts are avoided. This concept leads to lower construction costs of about 30 % compared with conventional building [32] in addition to considerable savings in maintenance of the network since there are no shafts. The advantages and disadvantages of conventional building and flat laying are compared in Table 10-1.

Table 10-1: Flat laying compared to conventional building, according to [32]

	Advantages	Disadvantages
Conventional Building	+ retrofitted connections + draining possible, and simple repairs and connection work	- higher underground engineering costs in order to keep to the defined gradient - shafts (construction and mainten-ance) - venting and draining fittings
Flat Laying	+ no venting and draining shafts and the appertaining fittings + lowest possible excavation mass from underground engineering + possibility to lay pipes under or on top of obstacles	- expensive connecting techniques (expensive shaped pieces and steel fittings) - inclusion of air must be avoided - possibility of impurities getting into the heating water as a result of metal shavings and scaling - disturbing occurrence of water at places where work or repairs are being carried out

In particular, difficulties in the operation of such district heating networks are used as arguments against flat laying. However, operators of these pipelines, admit that the advantages of flat laying outweigh the disadvantages by far.

The venting of pipelines generally does not present a decisive problem. The operating staff must be careful when filling the system to keep the amount of air trapped in the pipes to a low level. Any remaining quantities can be removed by means of the venting devices at the house connecting stations or by means of the venting devices at the end of the line, if these are available. For larger pipelines venting and emptying can be carried out when necessary by tapping the pipe when repairs are being prepared.

Since repairs should be carried out without disrupting the operation as far as possible it should be attempted to carry out the work on the water-filled pipes at operating pressure and temperature. As an example, this is often possible when connecting a new customer. For such work, the operating parameters (pressure and temperature) must be reduced as far as possible. However, there are cases such as damage and making connections where it is impossible to avoid shutting down the operation. For this, the pipeline section is made pressureless and cooled down to such an extent that work can be carried out on the pipeline and if necessary it can be partially or completely emptied.

In the following, working techniques and tools, specially developed for these purposes and proved in operating practice, will be described. To some extent these are expensive tools but others are only simple aids. The practical man should select whatever is most interesting. The techniques for drilling into pipes will not be mentioned since these were described in an earlier IEA-report [33]. This report is generally available and both the tool as well as the service are offered by many specialised companies in their catalogues today.

11 Shut-Down Techniques for Preinsulated Pipes without Fittings

Should pipelines, without any, or too few, shut-off devices, have to be shut down and emptied, depending on the situation, appropriate measures will have to be taken. It is important to know whether the shut-off device has to be tight to the full pipeline pressure or must only hold out against a lower pressure to prevent emptying of a pressureless pipeline and whether the pipeline is still at the operating temperature.

Especially in the case of flat laying, it is often impossible to estimate how much water has to be removed or how long the process will take. Often there is a remaining quantity of water which flows very slowly and prevents welding work. Several aids have been described in Section 11.5.

In the following, the most often used and proven methods of shut-down will be described.

11.1 Pipe freezing

Pipe freezing is a simple process to plug water filled pipes. It uses the solidifying of water when cooled below the freezing point. The ice plug forms a local stoppage which is tight against high pressure. The pipe blockage can be removed by simply melting the ice. Although this process works simply, it requires very special know-how in order to apply it correctly as well as particular care in its usage.

For pipe freezing, a cooling collar, filled with a cooling agent, is wrapped around the water-carrying pipe. The cooling agent could be alcohol, liquid gas (nitrogen), CO_2-dry-ice or brine.

The cooling agent takes the heat out of the water in the pipe and causes it to freeze. A layer of ice is formed on the inside of the pipe and this becomes increasingly thick until the pipe is completely filled. The ice plug so formed wedges itself in the pipeline and blocks the cross section. The precondition for the reliability of this process is that the physical conditions in the pipe must be fulfilled so that the water can freeze (no circulation) and that an existing ice plug stays in place for the period required for repair and does not thaw out too soon.

The conditions for a reliable application of pipe freezing are:

– The medium pipe must be of steel or copper; steel pipes are not allowed to be corroded to any noticeable extent.

– The pipe must be completely filled with water.

– Water should not circulate in the pipe, even convection in vertical or sloping pipes can be damaging.

The particular advantages of pipe freezing are:

\+ Freezing can be applied to almost any point in the district heating pipeline.

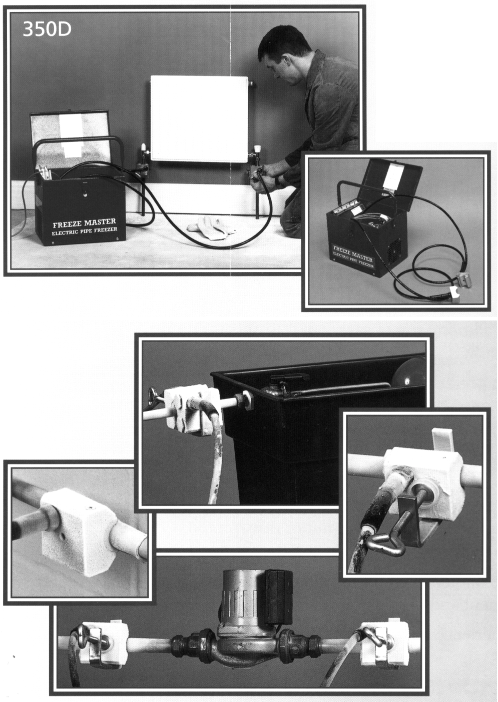
\+ Draining, refilling and venting are only necessary for a very short pipe segment. Water losses are small.

\+ The heating water remains free of foreign materials and impurities.

The device for pipe freezing can consist of a compact machine which prepares the cooling agent and perhaps also pumps it around. Such devices are suitable for small pipelines. The device can also consist of individual components, which are connected together when required at the building site. This is the normal case for freezing pipelines up to ca. DN 300.

In the following, 2 examples of pipe freezing are shown: on the one hand for small pipelines and on the other for larger district heating pipelines. Figure 11-1 shows a portable compact device in use, as well as in other possible applications.

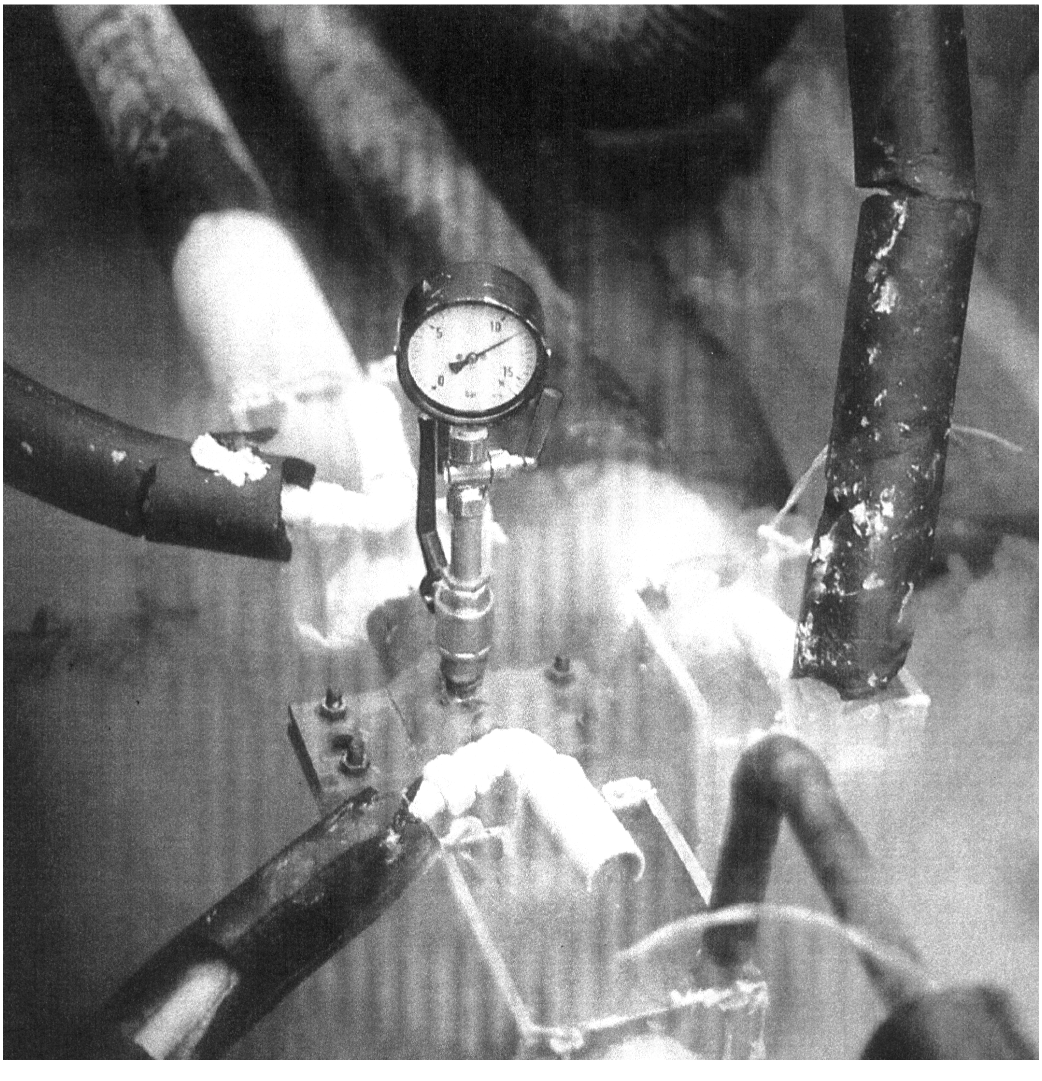
Fig. 11-1: Pipe freezing for small pipelines
top: compact device, Freeze Master, Londen UK
bottom: cases of application



Large pipelines up to about DN 300 are frozen using liquid nitrogen. Large quantities of liquid gas are needed for this and freezing takes up to several hours. Such work is usually carried out by special companies on commission, as it is not worth supply companies keeping their own logistics for liquid gas supply, the necessary tools and trained personnel for such work.

The freezing device for a medium-sized district heat pipeline is shown in Figure 11-2. It is easy to recognise the containers, which surround the pipeline and contain the liquid nitrogen. In the picture one can also see a pressure monitor. This is necessary when the ice plug is growing in a volume of water restrained on both sides. The increase in volume could otherwise lead to a violent rupture of the pipeline.

Figure 11-2: Pipe freezing of a district heating pipeline with liquid gas, MVV Energie AG Mannheim, Germany



Altogether, pipe freezing is a suitable process for provisionally closing a pipeline. The only disadvantage is the high cost required for freezing larger pipe diameters. The safety of the working personnel must be particularly taken care of, as particularly in the area of district heating there is a danger that ice plugs can only be produced slowly and that they melt unnoticed. For this reason, the district heat associations and the industry have produced working regulations to guarantee the safety of personnel. If these regulations are adhered to then the public controlling authorities have no objections to the use of pipe freezing of district heating pipelines, for instance, in Germany based on [35] et al.

Pipe freezing has to be prepared carefully. The working progress is normally recorded in a works protocol, an example is given in [35].

11.2 Shut-down bags

Shut-down bags for closing pipelines temporarily are elastic hollow bodies, which are inserted in the pipeline and blown up with gas under pressure. They are pressed by the pressurised gas against the inner wall of the pipe and close the pipe cross-section. Shut-down bags are usually used together with bagging systems, see Figure 11-3.

Bagging systems were developed for gas supply. The working procedure to produce a closed pipe is described by Figure 11-3: While the (gas) pipeline is in operation, a pipe connecting piece is inserted according to the tapping method. The bagging system can be connected to this connecting piece. With the bagging system the shut-down bag is brought into the pipe and blown up to such an extent that the pipeline is closed. The bagging system makes pressure release on the separated space and even rinsing possible. For safety reasons in gas supply, double bags or two separate bags are inserted next one to another.

Shut-down bags can only be used when the flow through the pipe is stopped. As the bags are of elastic plastic the temperature during application should not be too high, about 60 °C. Shut-down bags available today can only hold up against pressures up to max. 1 bar.

For these reasons, there are very narrow limits set for the use of shut-down bags in district heat supply. The pipeline must be separated and cooled down. As the bags are only tight against low pressures, they can be used for closing pressureless pipeline sections, e.g. in an arrangement as sketched in Figure 11-4. Shut-down bags are also available for very large pipe diameters.

Fig. 11-3: Bagging system

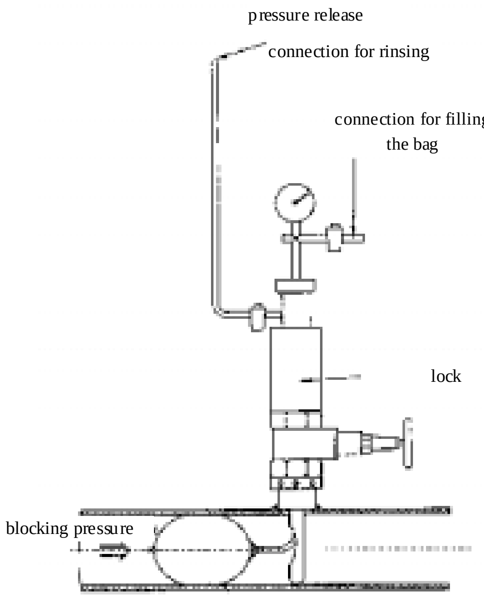
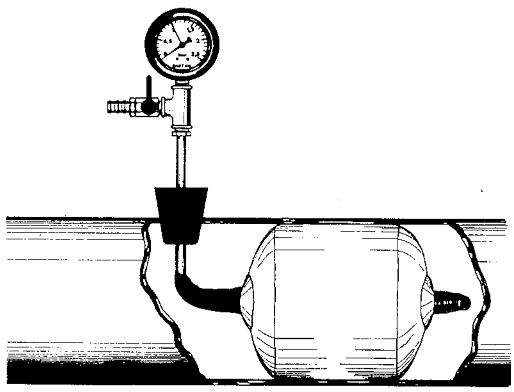


Fig. 11-4: Shut-down bag

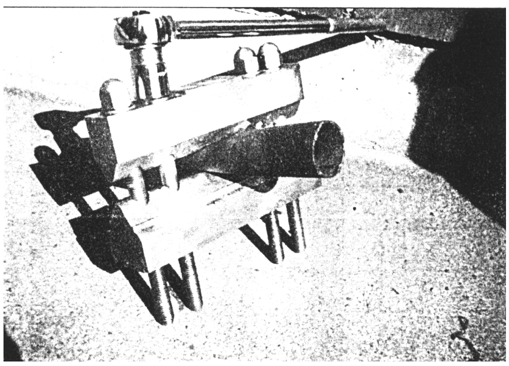


11.3 Pipe squashing

Squashing is the act of pressing the pipe together with a tool. The pipe walls are pressed together until the pipe is flat and the cross-section closed. For metal pipes, which are considered here, the pipe stays closed. On the other hand, plastic pipes with their elasticity and relaxation can be squashed shut for a short time and finally freed again.

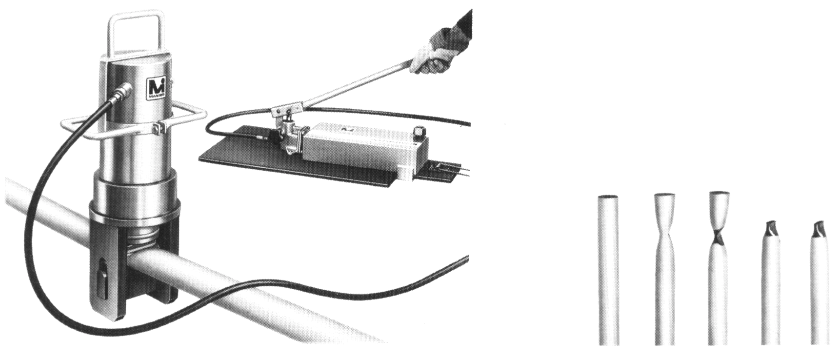
For squashing, the pipe is fixed between 2 parallel blocks of a tool which then presses them together. For small pipelines, the pressing forces are small and can be produced manually. Figure 11-5 shows a simple tool for manual operation.

Fig. 11-5: Squashing tool for small pipelines [16]



Greater forces are needed for pipelines of larger diameter and these are produced by hydraulic presses. Figure 11-6 shows a pipe squashing device with hydraulic drive, which is suitable for steel pipes up to DN 80. The tool with the hydraulic cylinder can be recognised with the hydraulic pump on the left of the picture, the squashed pipe is on the right. The company Tonisco, Tampere/Finland offers these hydraulic tools for up to DN 200. Squashing is particularly interesting for a quick blockage of a pipe in the case of an accident.

Fig. 11-6: Hydraulic pipe squashing device for steel pipes up to DN 80, Photo Manibs, Remscheid, Germany



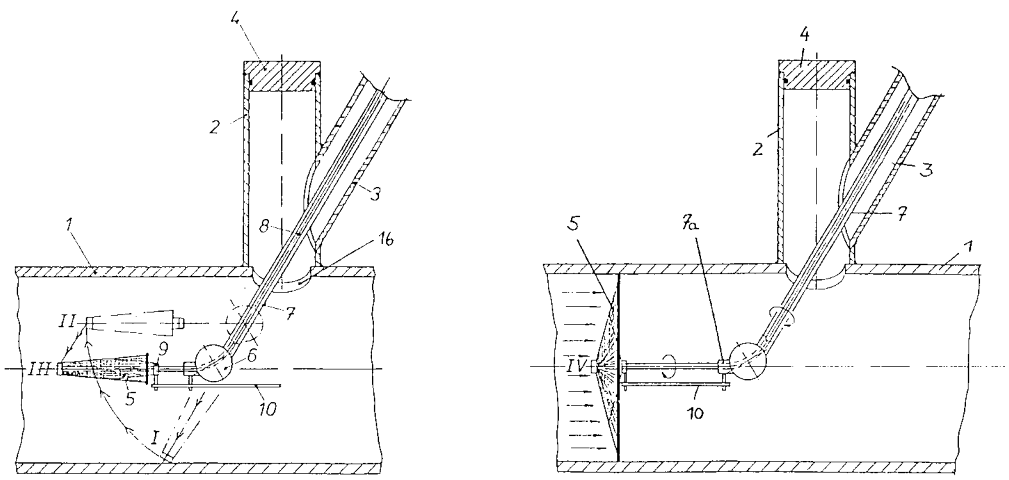
11.4 Shut-down shield (Development of MVV)

Since there are no simple possibilities for shutting down larger district heating pipelines, MVV has concerned itself with the development of a device which should be able to be applied under operating conditions. The concept for a shut-down shield has been developed and the shield has meanwhile been patented [34].

The shut-down shield is a membrane which opens like an umbrella and which is inserted axially in the pipeline. When open, the shield lies tight against the pipe wall and completely closes the pipe cross-section.

The working procedure for the shut-down shield can be seen in Figure 11-7. The picture on the left shows the closed shield being brought into the pipeline. On the right is the open shield which closes the pipeline.

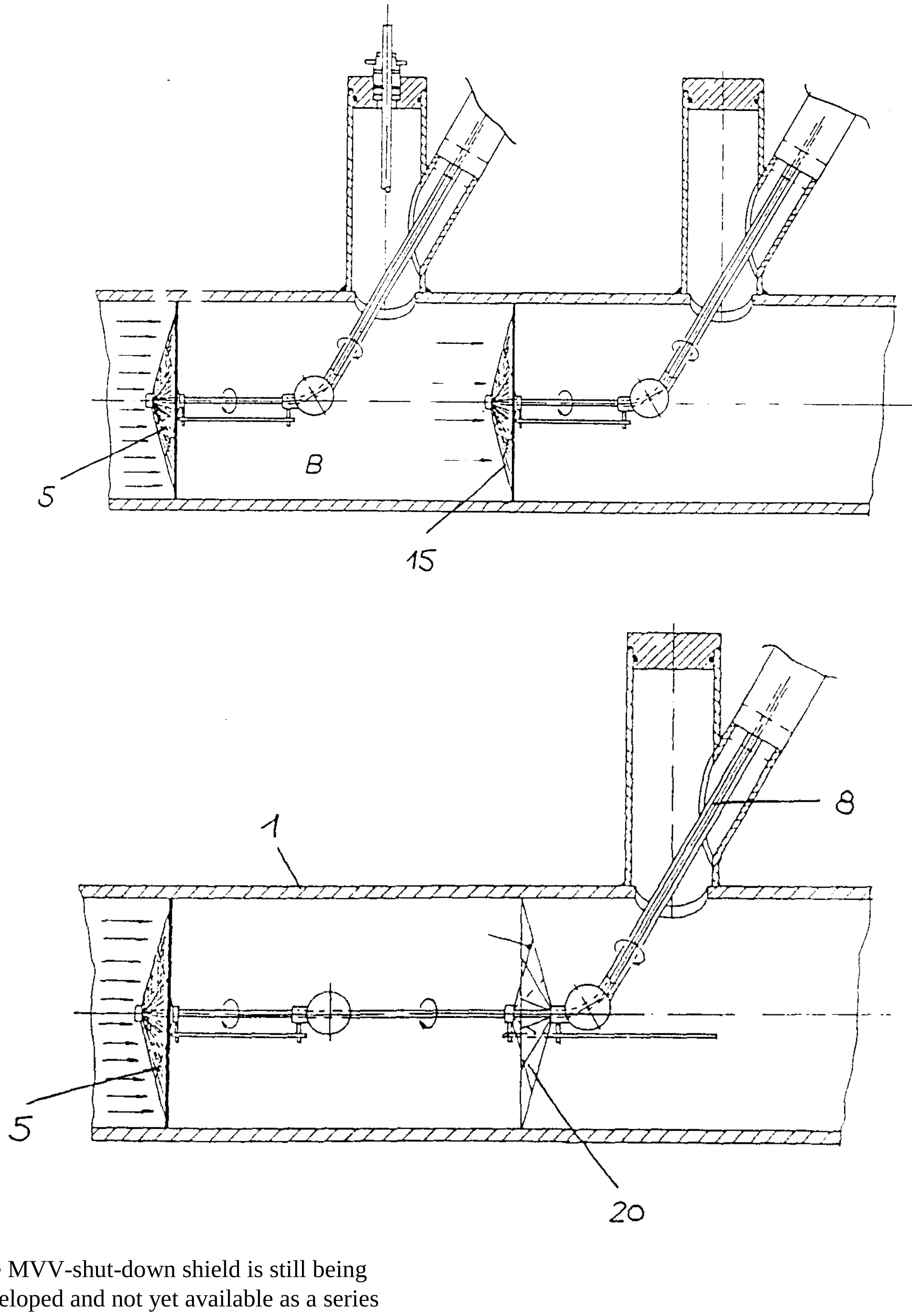
Fig. 11-7: Shut-down shield MVV Energie AG Mannheim, presentation of the principle as shown in the patent documents



The closure is achieved as follows. Using a drill a connecting piece 2 is fitted to the pipeline 1. The shield compartment 3 is found on the side of the connecting piece. The shield 5 is pushed at an angle into the pipeline with the restraining pipe 7. It is steered by the pipe wall into the axial direction and can be opened with the help of the screwed spindle 8. For dismantling, the shield is closed again and removed through the compartment and a lock. The connecting piece stays on the pipeline.

There are 2 variants of this method. In the first case, two shields are fitted so that the space between the shields can be controlled for any leakage, see Figure 11-8 at the top. In the second it is foreseen that there is an arrangement to guarantee tightness against higher pressure. Here, a double shield is used whereby the actual tight shield is guyed with a second shield which has no sealing membrane, see Figure 11-8 at the bottom.

Fig. 11-8: Variants of the MVV-shut-down shield
top: double closure for increased working safety
bottom: shut-down shield for higher pressure



The MVV-shut-down shield is still being developed and not yet available as a series product.

11.5 Simple barriers

When the pipeline lies flat underground it often takes a long time to completely empty a separated section and the time required can hardly be estimated. Small quantities of water often flow hours after draining and hinder the progress of repairs, as welding cannot be undertaken when water is flowing. In such cases the mechanics often help themselves by using simple aids. Usually, it is sufficient to hold back the water flow in front of the weld for a short time. For this purpose, damming disks can be used for example. There are also pipe plugs which can keep the pipeline closed under pressure.

Damming Disks

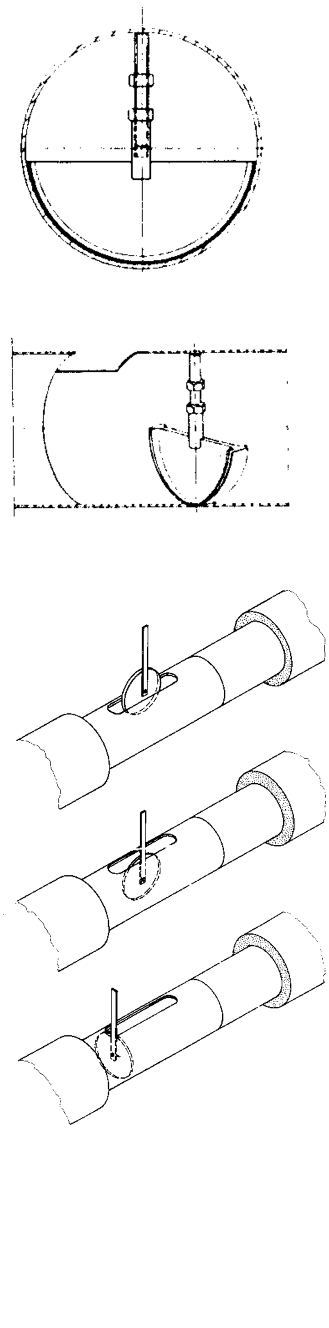


Fig. 11-9: Damming disks
top: as used in Finland [16]
bottom: Type MVV Energie AG Mannheim, Germany

A damming disk is, for instance, a semicircular disk with a sealing area on the circle contour, see Figure 11-9 on the left. The sealing area is guyed with a spindle against the pipe vertex. With this arrangement the working area can be kept dry for a certain time, until the water level reaches the top of the damming disk. If this period of time does not allow the welding to be completed then the water can be pumped out so that it does not get over the barrier and into the working area. Another form of damming disk, type MVV, is inserted through a longitudinal slit at the vertex of the pipe, see Figure 11-9 on the right.

Plastic Sealing Mass
As alternative to the damming disk, the operating staff at MVV have developed a technique for small pipelines using a plastic sealing mass. The working procedure is as follows: preparations are made for welding and then the low water flow stopped by means of a ca. 1 to 2 cm high dam made from a plastic sealing mass and the welding carried out in the lower pipe vertex. The sealing mass remains in the medium pipe, dissolves in the district heating water or is dispersed. A white clay containing 40 % fire-clay (German term "Lette") is used as sealing mass.

Locking Plug
A pipe locking plug is a tool with which a complete, pressure resistant pipe closure can be produced. Figure 11-10 shows a commercial plug which is on sale for pipes up to DN 500.

Fig. 11-10: Pipe locking plug for DN 80 to DN 500 (manufactured by Manibs, Germany)

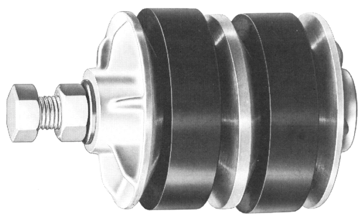
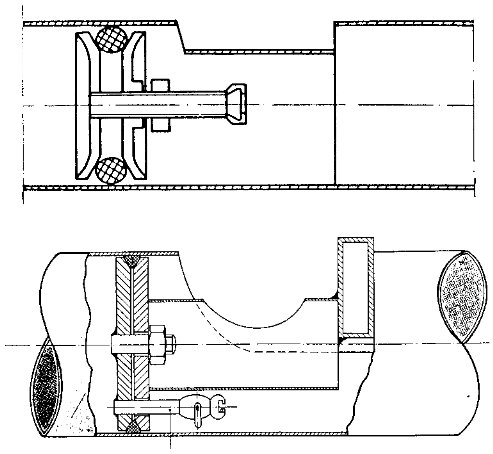


Figure 11-11 shows two Finish constructions, which additionally offer a connection for water or compressed air. On the left is an arrangement for low over-pressure, on the right the system includes an abutment for high internal pressure.

Fig. 11-11: Pipe locking plug with connection for pressure pipeline [16]
top: simple arrangement
bottom: with an abutment for high internal pressure



12 Draining the Pipeline

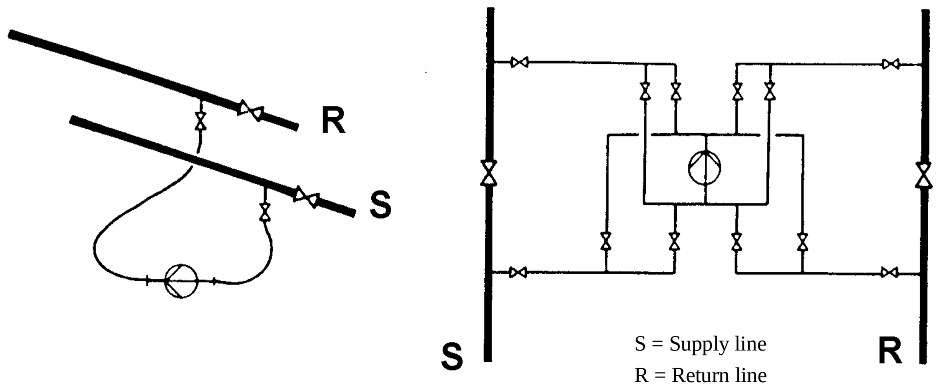
When emptying a pipeline a loss of district heating water has to be avoided since expensive, treated fresh water is needed to refill the system. Impurities could also make it necessary to discharge the district heating water into the waste-water system and replace it with new.

12.1 Draining by recycling

A cost-favourable possibility for draining a length of pipe is either to pump the water into the other length of pipe or to conduct it to a pipeline section on the other side of the blockage. In this way, the district heat water is not lost and so is available for refilling the pipe.

Supply companies have built devices combining a pump with a control for fittings so that as many cases of application as possible can be covered. An universal connecting device is shown in Figure 12-1 [16]. By arranging the fittings accordingly, the discharge flow of the pumps can be adapted to all possible pumping tasks.

Fig. 12-1: Recycling of the district heat water when draining [16]
left: simple connection to a pump
right: universal connecting device



12.2 Discharging into the waste water system

If draining the district heat water into the sewage system cannot be avoided then a maximum temperature (e.g. 35° C) is not allowed to be exceeded and if necessary the water has to be cooled down. For practical reasons, cooling is achieved by mixing with cold water. This is easy and can be carried out without special equipment. The mixed temperature is normally determined at random.

Many supply companies use water spraying pumps to pump off the district heat water. These pumps offer the advantage that they guarantee the cooling down of the district heat water at the same time.

13 Cooling Down the Pipeline

Pipelines taken out of operation must first be cooled down before work can be carried out on the medium pipe. If the separated pipeline is cooled down naturally by losing heat to the earth, then the cooling process can take a very long time. To keep the cooling down time short, for a planned repair, the operating temperature in the affected section of pipeline will be set as low as possible well before the work starts.

One possibility to reduce the temperature of the supply pipeline is to pump cooler returning water into the supply pipe. In this way the peak temperature can be relatively quickly reduced.

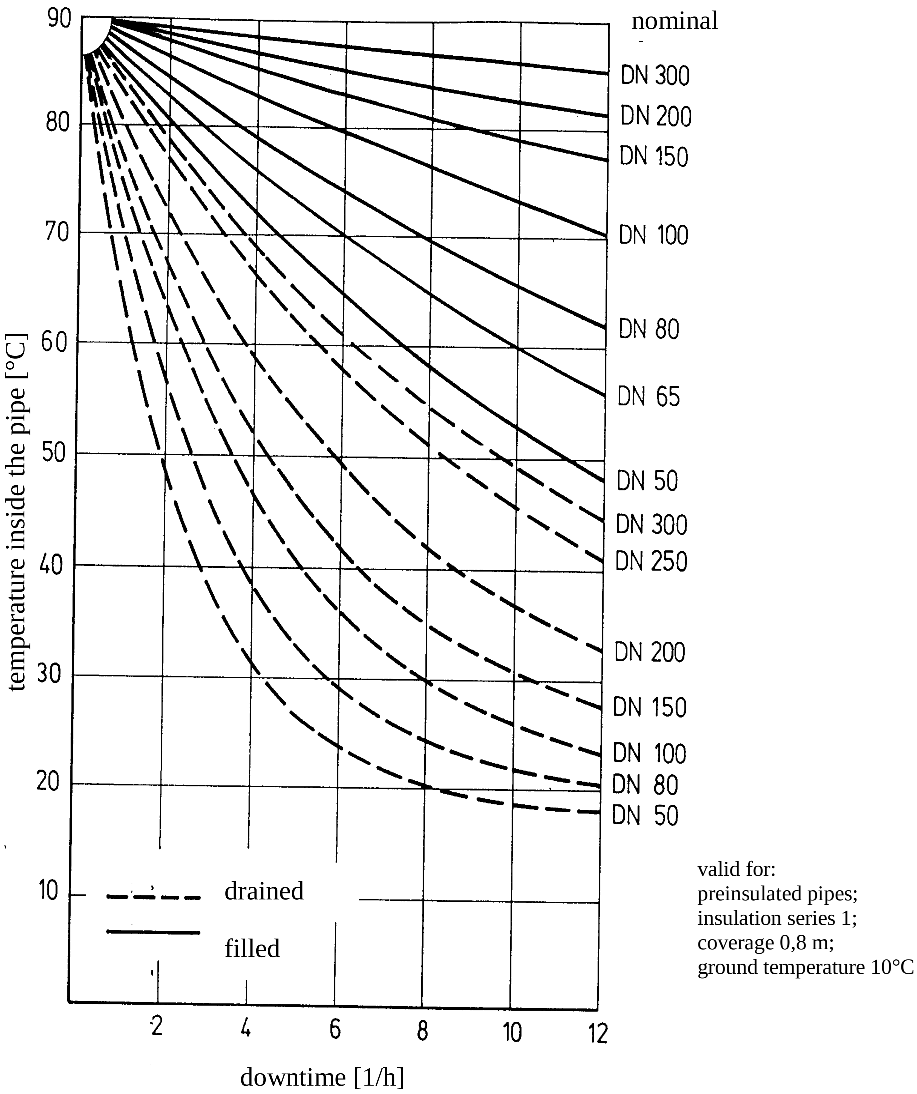
The natural cooling down of a pipeline is determined by many factors, the most important being:

- is the pipeline filled with water or not
- diameter of the pipeline
- insulation (insulating series of the pipe material, thermal conductivity of the soil)

Cooling as a factor of time of a preinsulated pipeline is shown in Figure 13-1. The diagram was developed as a worksheet for the operating personnel of MVV Mannheim. From the diagram it can be estimated what cooling times must be calculated in scheduling repair work.

The diagram shows the large difference between small and large pipelines. Moreover, it can be seen that drained pipelines require only a fraction of the cooling time necessary for filled pipes.

Fig. 13-1: Cooling times for preinsulated pipes



14 Repair Techniques

14.1 Provisional repairs

Leaks in district heating pipelines occur more often for high performance (in cold weather). At these times interruptions to the supply are particularly unwelcome. If conditions allow, a provisional repair will first be carried out and the damage will be completely removed later, at a more favourable point in time.

For a provisional sealing of leaks in smooth pipeline components, repair clamps have proved themselves in many instances. A repair clamp is a collar, which is fixed with screws around the pipe. A soft seal is fitted inside the collar, so that the leak is sealed. The final repair can be postponed for several months up to a max. of 1 year using repair clamps.

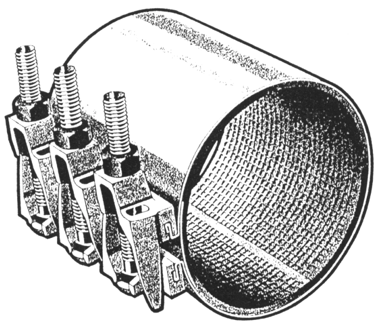


Fig. 14-1: Repair sleeve, as one part [16]

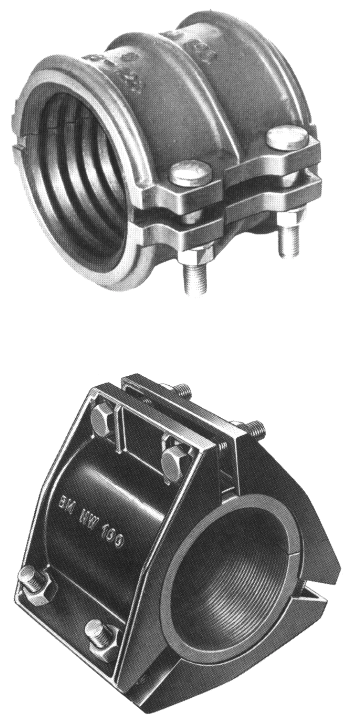


Fig. 14-2: Repair sleeves, divided into 2 and 3 parts

Figure 14-1 shows a one-part repair sleeve, in which the seal of rubber with profile can be clearly seen. For larger pipelines sleeves divided into 2 and 3 parts are available (up to DN 300 and DN 600 resp.), see Figure 14-2. Subdivided sleeves can be used for the larger diameter sector.

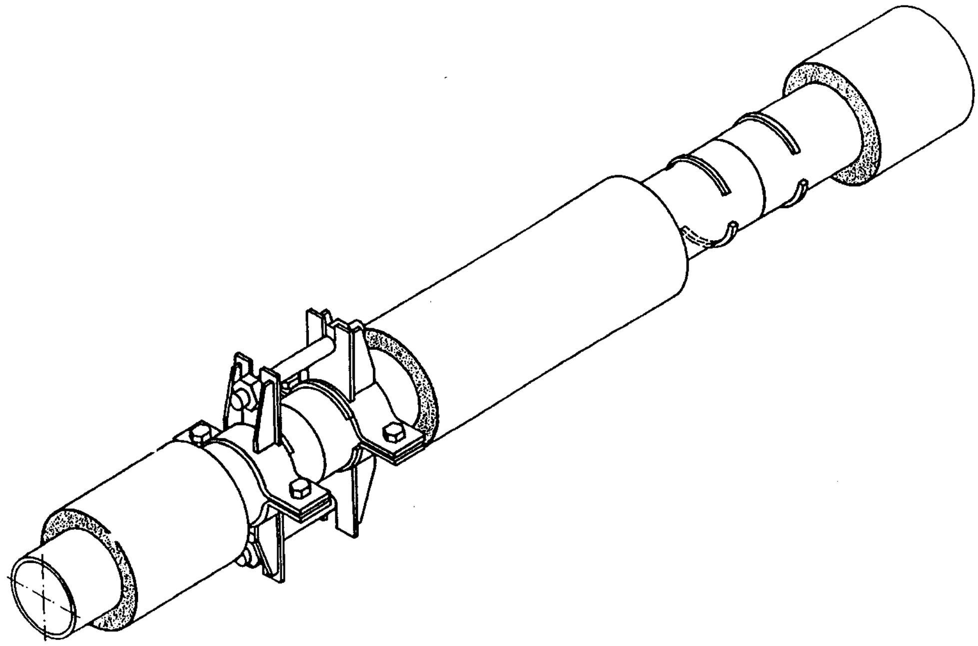
14.2 Preinsulated pipes under axial stress

According to the laying process and operating temperature, district heating pipelines can be under high axial stress. When the pipeline is separated or the pipeline cross-section noticeably weakened, for instance by a large tapping, then the stress condition must be taken into account. If necessary, static calculations must be undertaken.

In the following, 2 cases of repair will be described to serve as examples for the normal procedure. Figure 14-3 shows the replacement of a pipe section in the gliding section of a pipeline [20]. Normally one would proceed as follows:

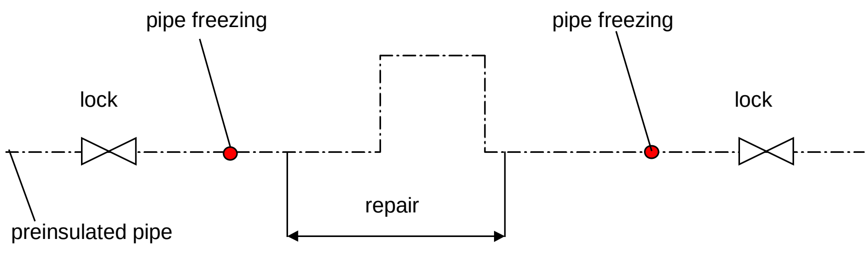
- The new pipe is prepared for installation by being equipped with retaining clips. The pipe has the same length as the section to be cut out.
- The pipe pieces which are to be connected to the new pipe are prepared for the addition of the retaining clip.
- The damaged piece of pipe is separated from the pipeline.
- The new piece of pipe is inserted and the retaining clips mounted.
- Welding completed and the clip dismantled.
- Insulation put in place again.

Fig. 14-3: Retaining clip for preinsulated pipes



A possible alternative for a repair in the area of high axial stresses is the installation of an U-compensator. In this way, segments in a once fixed section can be changed into a gliding area. Figure 14-4 describes such a repair, in which the repair section is bounded by 2 pipe freezings. The installation of an U-bend is generally avoided as this is an expensive solution requiring a lot of space.

Fig. 14-4: Repair by inserting an U-compensator



When exchanging pipeline sections after a shut-down it is not always easy to replace the damaged section by a new pipe rod of identical length. When installed the length of the section to be repaired cannot be determined exactly, because through axial stresses it is twisted or squashed and, in addition, shows a temperature-dependent dilation. It is however not necessary to keep to very narrow tolerances. On smooth pipelines the tough steel material can tolerate one small over-stressing as a result of a repair. However, care must be taken when the pipeline is found in the area of branches and repairs. Overloading should not be allowed to occur here.

14.3 Replacing pipeline sections installed in piggy-back lines

In the case of pipelines which are laid one above the other, the supply pipe is found underneath as a result of the lower thermal losses. For maintenance purposes, the question has to be asked, how can a pipeline section be exchanged if it lies underneath.

The following procedure is foreseen, see Figure 14-5:

1. The trench is dug asymmetrically to the pipe axis, so that the working space on the one side is next to the pipes, No. 1.

2. The damaged piece of pipe is separated and laid in the trench to the side next to the pipe route; it is then removed.

3. The new pipe is brought into the existing gap and installed.

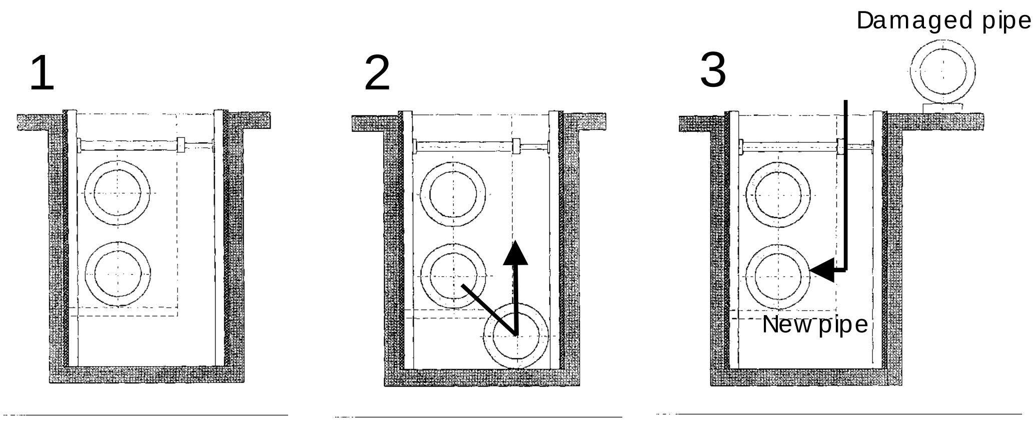


Fig. 14-5: Repair technique for preinsulated pipes installed one above the other

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