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SR 76-16

Special Report 76-16

UTILITY DISTRIBUTION SYSTEMS IN SWEDEN, FINLAND, NORWAY AND ENGLAND

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November 1976

CORPS OF ENGINEERS, U.S. ARMY

COLD REGIONS RESEARCH AND ENGINEERING LABORATORY

HANOVER, NEW HAMPSHIRE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Special Report 76-16 (14) CRREL-SR-76-16

2. ~~GOVT ACCESSION NO.~~

3. ~~RECIPIENT'S CATALOG NUMBER~~

4. TITLE (and Subtitle): (6) UTILITY DISTRIBUTION SYSTEMS IN SWEDEN, FINLAND, NORWAY AND ENGLAND.

5. ~~TYPE OF REPORT & PERIOD COVERED~~

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): H.W.C. Aamot, T.T. McFadden

8. CONTRACT OR GRANT NUMBER(s): (12) 126p.

9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: (16) 4A762719 AT06/03/003 (17) 03

11. CONTROLLING OFFICE NAME AND ADDRESS: Directorate of Military Construction, Office, Chief of Engineers, Washington, DC 20314

12. ~~REPORT DATE~~: (11) November 1976

13. ~~NUMBER OF PAGES~~: 125

14. ~~MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)~~: (10) Haldor W.C./Aamot, E.F./Lobacz, A.F./Wuori, Terry T./McFadden

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. ~~DISTRIBUTION STATEMENT (of this Report)~~

Approved for public release; distribution unlimited.

(9) Special rept.

17. ~~DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)~~

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

District heating	Public utilities	Waste disposal
Domestic	Sewage	Waste management
Handling	Sewage disposal	Water
Heat pipes	Solid wastes	Water supplies
Heat transmission	Transmission lines	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study reports on new developments and special problems or solutions in water distribution systems, sewage and solid waste transport systems, heat distribution systems and electric transmission systems. Cold weather considerations are highlighted. For water and sewage systems, the use of ductile iron and plastic materials for pipes is reported. The use of heating, insulating or shielding of the pipes for frost protection is of interest. Some developments in tunneling technology were identified. Pneumatic solid waste

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Unclassified 037100

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) collection and vacuum sewage collection represent new developments. For heat distribution, the many different types of pipe and insulation systems used are described. Good moisture control in insulation is emphasized. Developments in long distance heat transmission are discussed. With electric distribution, the use of self-supporting aerial cables is a new development. With transmission, problems of icing and countermeasures are discussed.

PREFACE

This report was prepared by Dr. Haldor W.C. Aamot, Research Mechanical Engineer, Construction Engineering Research Branch, Mr. E.F. Lobacz, Chief, Experimental Engineering Division, Mr. A.F. Wuori, Chief, and by Dr. Terry T. McFadden, Chief, Alaskan Projects Office. Dr. D.R. Freitag is Technical Director and Col. R.L. Crosby is Commander and Director of the U.S. Army Cold Regions Research and Engineering Laboratory.

The work was funded by the U.S. Army Corps of Engineers under DA Project 4A762719AT06, Task 03, Work Unit 003: Utility Distribution Systems in Cold Regions. The objective is to develop new or improved criteria for design and construction of utility transport systems in cold climates.

The warm welcome given by all the people and offices visited during the trip and their exceptional cooperation in providing available information is gratefully acknowledged.

The citation of commercial products and company names in this report is for information only and does not constitute endorsement or approval. Also, the citations are given merely as examples, not as the complete range of available choices.

CONTENTS

BACKGROUND

This report presents information on utility distribution systems, gathered on a study trip to Scandinavia and Great Britian. The information concerns new technology and materials and cold weather related problems and solutions. The distribution systems involved are water and sewage lines, vacuum sewage and pneumatic solid waste collection pipe lines, heat distribution lines and electric transmission lines.

In Sweden, much information was obtained on plastic pipes for water and sewage lines and frost penetration and protection. There are large district heating systems in operation and much information was found on heat distribution pipe systems and long distance heat transmission.

From Finland, information was obtained by correspondence on heat distribution pipe systems and self-supporting aerial cables.

In Norway, where almost all electricity is produced in hydroelectric stations, much information was collected on icing problems of electric transmission lines and on self-supporting aerial cables for distribution. Also, information on frost penetration and protection of water lines was obtained.

In England, a wealth of information was gathered in London where the water and sewage systems are among the oldest and largest in the world and where some materials and methods have a long history of success and other new ones are being introduced. District heating technology is also highly developed but large systems have not yet evolved. Pneumatic solid waste collection systems are being introduced.

The report provides information on new technology which may be useful in the planning and design of Corps of Engineers projects, but may also be useful to other agencies.

The report is organized by subject areas, starting with water and sewage and continuing through electricity and heat. The information in each subject area includes that from the various countries where it was obtained.

1. Water distribution lines.

1.1 Extent of research.

Water distribution lines were studied in Sweden, England and Norway. Professor L.E. Janson of the Water Projects Office (VBB) in Stockholm was interviewed. He has written many articles and a text on the subject of water and sewage lines and is one of the foremost authorities on this subject in Scandinavia.

In England, personnel of the Thames Water Authority were interviewed and gave considerable information on water and sewage problems and on techniques used in London and throughout England.

In Norway, personnel of the Norwegian Building Research Institute in Trondheim and Oslo were contacted and interviewed concerning Norwegian standards and frost protection techniques. The research was conducted over a three-week period during the spring of 1975.

1.2 Piping materials and sizes.

The use of plastic, particularly unplasticized polyvinyl chloride (UPVC) and high density polyethylene (HDPE) is more extensive in Europe than in the United States. Many of the codes have been modified in Europe to allow the use of plastic piping and it is used extensively, particularly in corrosive soils. It has found much favor in its ability to carry the needed loads, its ease of installation, and its ability to resist corrosive conditions in the soil.

During the ten-year period from 1960 to 1970 the consumption of polyvinyl chloride in the Nordic countries has increased from about 30,000 tons in 1960 to 150,000 tons in 1970 (Janson, 1974). Recommended lifetime for plastic water piping has been set at fifty years.

Two particular disadvantages have been noted with the use of plastic pipe. They are (1) the inability to thaw the pipe with low voltage high current techniques as is possible with metal pipes and (2) the inability to detect leaks with the use of audio listening devices. Plastic pipes can, however, be thawed by the use of external thaw tapes, a technique commonly used in this country as well as Europe. This partially overcomes the first disadvantage.

Several other advantages to plastic pipe are listed by Janson (1974). They include the fact that the inner surface of the pipe is very smooth, resulting in lower frictional loss and thus higher flows for a given diameter than with rougher metallic pipes (particularly when compared to cast iron). Plastic pipes are flexible and can deform with stresses to some degree, thus eliminating some breakage that might occur in rigid pipes, such as concrete, ceramics, or cast iron. Plastic pipes are light, therefore lowering the transportation costs to the site. The ease of installing the lighter pipes also reduces labor costs. In addition the low thermal conductivity of plastics means lower heat losses. Therefore, the risk of freezing is somewhat less.

Negative factors concerning plastic pipe include the fact that plastics react differently to stresses than do metals. Therefore, not only must the stress but also time and temperature factors be considered in the design of plastic piping systems. In addition, plastic pipes require a more carefully controlled backfill material to assure that no heavy or sharp materials damage the pipe when the trenches are backfilled. Finally, the quality control by manufacturers of plastic pipe is sometimes lacking and different manufacturers can produce pipes of different qualities.

Solvent cementing to join polyvinyl chloride is the subject of considerable controversy in Europe at this time, with the French and the English objecting to its use, while the Nordic countries do not appear to be as concerned. The prime objection to solvent welding appears to be age embrittlement of the solvent welded joint. Enough data on long term use of the pipe is not available to completely resolve the question. However, the English, particularly in London, have completely banned the use of solvent welding for connecting PVC pipe.

Prestressed concrete pipe is also used rather extensively. One particular application of its use is rather interesting. A technique that is beginning to find applications in this country involves the tunneling beneath roads without disrupting the roadway. When laying the waterlines, trenches are excavated up to a road and on the other side away from the road. Then a hydraulic ram is brought in which literally pushes a prestressed concrete pipe through the roadbed without disrupting the road. This of course is only possible in areas where the roadbed is not gravel. However, it has proven very acceptable as a means of avoiding disruption of traffic when waterlines must be laid across a roadway. In London, ductile iron has almost completely replaced cast iron. However, the English are quick to admit that many of the old cast iron pipes have been in service 150 years and have an expected life of at least 150 years more. Some concern is expressed that the use of shorter lifetime materials unnecessarily penalizes future generations who will have to replace these pipes at much higher labor and material cost. The additional cost of materials and labor at this time would be very small compared to the replacement cost in say 50 years.

In London, plastic linings are used to rehabilitate old lines which have started to fail. The technique used here is to draw the plastic lining, whose outside diameter is slightly less than the inside diameter of the old cast iron pipe, through the length of cast iron pipe that is to be rehabilitated. The cast iron pipe then acts as the tunnel and exterior support, but is no longer required to be watertight. The wall of the plastic liner is much smoother on the inside than the old cast iron pipe and it is found that even though its diameter is smaller, since its frictional head losses are less, nearly equivalent flows can be expected through the newly lined pipe. In addition, all leaks and losses are eliminated with this technique and installation costs are only a fraction of those for new lines.

In London, 80% of the water load is carried in 100 to 200 mm (4 to 8 inch) pipes. The water supply load for the city of London is 420 million Imperial gallons per day (1.9×10^6 m^3 day^{-1}) on the average, with peaks as high as 510 million Imperial gallons per day (2.3×10^6 m^3 day^{-1}). These are all supplied by the Thames Water Authority which is a new organization that has combined a number of other water and sewage groups to one municipal authority. London has approximately 10,000 miles (16,090 km) of distribution lines, the largest diameter of which is 60 inches (1524 mm) and this is steel. Slightly less than 50% of the new installations in London are classified as polyvinyl chloride. However, Holland appears to be using 100% UPVC in their new installations.

1.3 Depth of burial.

Since permafrost is only found in the very extreme northern parts of Scandinavia, no solutions to the problems faced in Alaska or Northern Canada can be expected. However, much of the experience and solutions to depth of burial problems found in Scandinavia would be applicable to northern parts of the continental United States. Considerable research has gone into the optimum depth of burial taking into consideration the construction costs involved in burial depth as well as the risk of freezing when lines are placed closer to the surface (Gunderson 1975 and Janson 1974). It has been found by L.E. Janson (1974) that considerable savings can be made in many soil types by considering the thermal regime which inhibits freezing around the pipe. Under these considerations, it is found that pipes can be buried considerably shallower than the conventional depth (which is below frost level commonly found in the area). In one test installation, at Nattavara, Sweden, savings of approximately 26% in snow cleared ground and 30% on snow covered ground were found when compared to conventional construction specifications. In rocky ground, savings as high as 48% of the trenching costs were found when compared to the more expensive conventional depth specifications.

Gundersen has done a great deal of work in determining the optimum burial depth for pipes. His paper entitled, Frostproofing of Pipes, contains many diagrams and nomograms for different soil types and weather conditions. Figures 1.1, 1.2, 1.3 and 1.4 are abstracts from this paper. The paper is in Norwegian; however, a CRREL translation is available (USACRREL TL 497). An earlier paper on Frost Insulation of Pipe Trenches is also available (USACRREL TL 217).

Burial of utilities in the older cities, such as Stockholm, which have existed for several hundred years presents a considerably different problem. The location of many utilities installed in years past is unknown. In addition, the compact, densely crowded conditions in the city make it very expensive and difficult to install by conventional means, that is, by trenching down the middle of the street. Swedish engineers have developed the art of rock tunneling to a high degree and it is considerably less expensive to tunnel 100 feet (30.5 m) below the city in the solid rock on which Stockholm rests. Tunnels 4 m (13.1 ft) in diameter are constructed through the area which is to be served by the utility. Vertical risers are then installed for each block so that all utilities, water, electric and sewage, can be taken to that particular block. Utilities are then distributed on the surface throughout the block. In this manner the entire utility system can be provided without once tearing up a street, disrupting traffic or causing loss or damage to older utilities during the trenching operation.

1.4 Heating of utility lines.

Heating of utility lines is considered in the overall economic analysis of the system and is used extensively in Europe as well as this country. No new technology in the method of heating was found. However, the reduction of burial depth due to the heat provided by the heating tape was considered in the overall design of the system and considerable savings in trenching costs were found to be possible by this means (Fig. 1.5). Heating is also considered standard in lines that have standing water and where freezing may be a problem due to insufficient burial depth of that particular portion of the line. This can be a problem in systems where the normal main is flowing adequately to prevent freezing, but some service lines, particularly ones to fire hydrants that are seldom used, may not be buried deep enough. In these cases, heat tapes were commonly used.

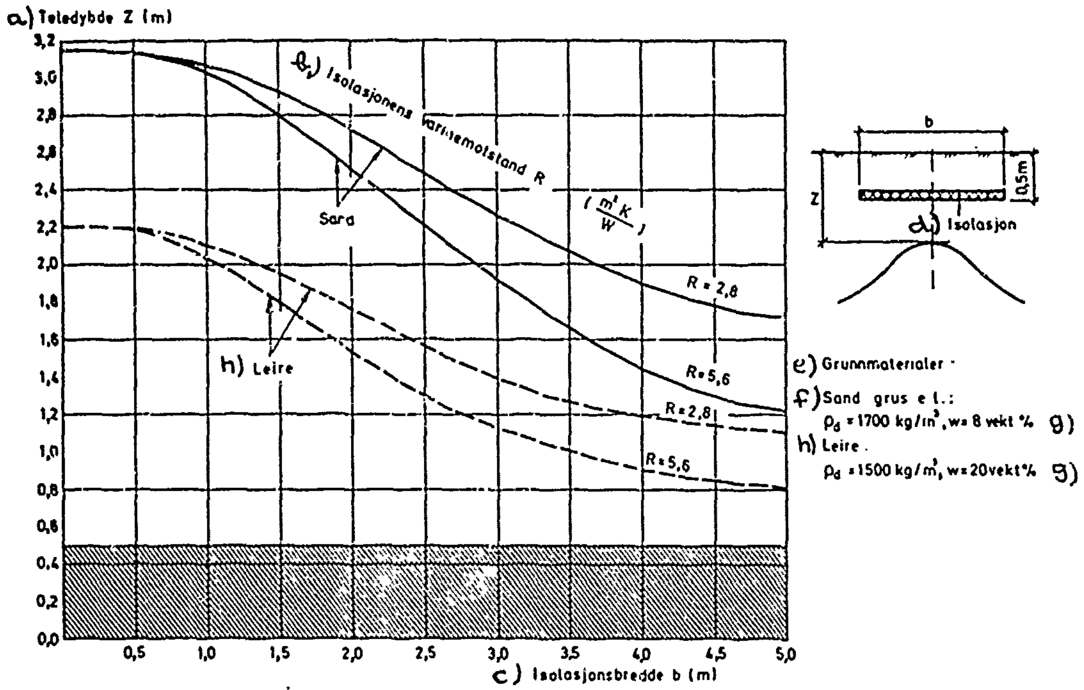

Fig. 1.1: Frost depth beneath middle of horizontal insulating layer. Frost amount F = 57,000 h°C and the mean annual temperature theta = 0.5°C key:

a. Frost depth
b. Insulation's thermal resistance
c. Insulation widths
d. Insulation
e. Materials:
f. Sands, gravel, etcetera
g. Weight
h. Clay

After Gundersen (1975)

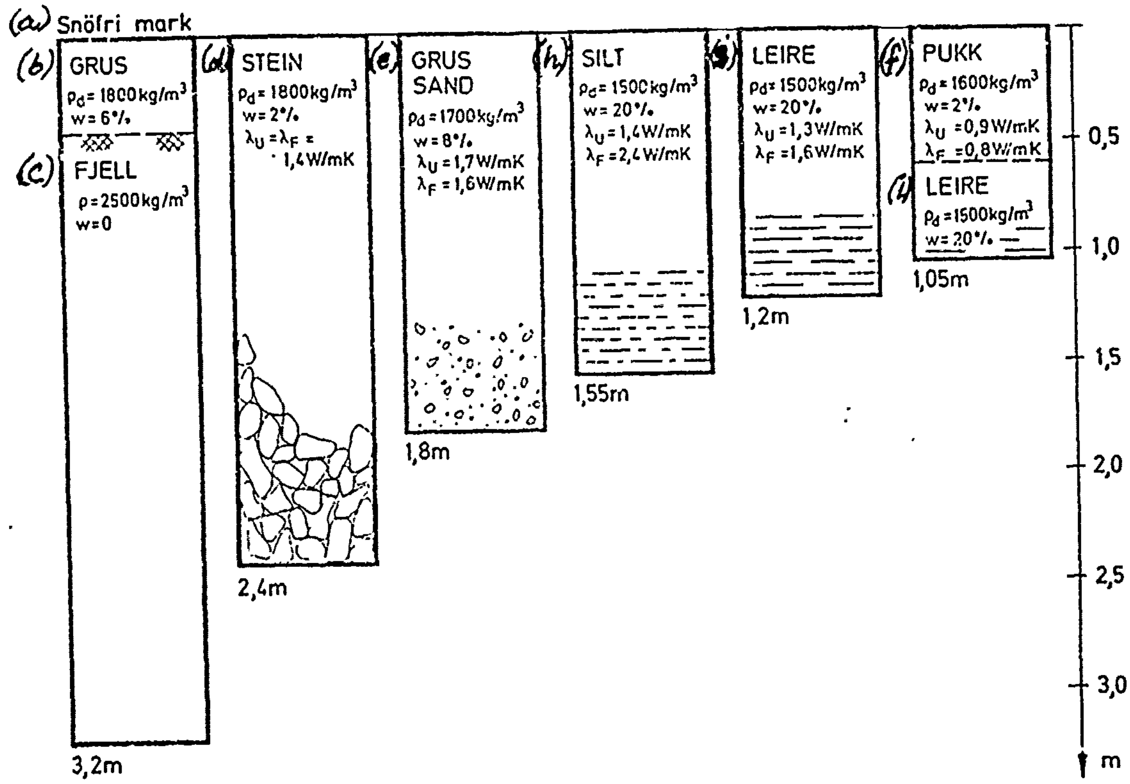

Fig. 1.2: Frost depths in various materials. The amount of frost is 25,000 h°C. The key letters are:

a. Snow free ground
b. Gravel
c. Rock
d. Stones
e. Gravel, sand
f. Gravel
g. Clay
h. Silt
i. Clay

After Gundersen (1976)

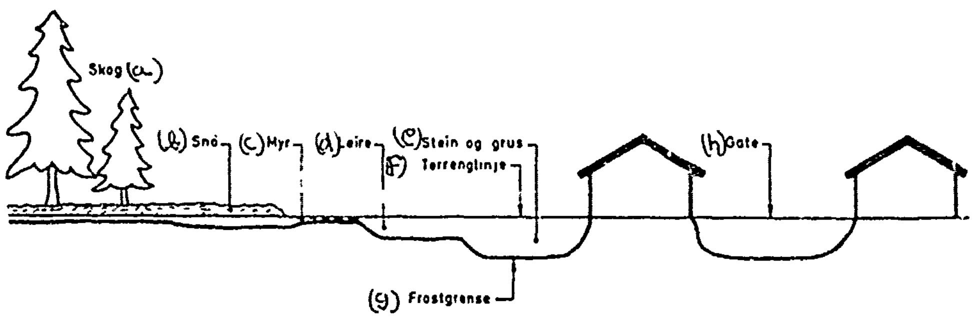

Fig. 1.3: Schematic representation of frost limits under various conditions. Key:

a. Forest
b. Snows
c. Marsh
d. Clay
e. Rocks and gravel
f. Ground line
g. Frost limit
h. Street

After Gundersen (1975)

(a) Materialbetegnelse	Tørr romvekt kg/m³ (b) pd	(c) Varmeledningsevne (W/mK) λ (d) frossen	(e) ufrossen	(f) Fuktighetsinnhold vekt % w	(g) Korreksjonsfaktor α
(h) 1. Stein (Pukk, Stein fylling, steinig grus)	1800	1.4	1.4	2	1.4
2. Sand og grus (Sandig grus, Steining morene)	1700	1.6	1.7	8	1.0
3. Silt (kvabb) (Mjelig morene, sandig mo)	1500	2.4	1.4	20	0.85
4. Leire og blandingsjord (Leirholdige morenearter)	1500	1.6	1.3	20	0.7
5. Torv	200	1.2	0.5	100	0.3

Fig. 1.4: Multiplication factors for determination of frost depths in various materials. Maximum frost depths for sandy gravel without snow cover have been determined from the frost depth map of Norway. Key:

a. Material designation
b. Dry Weight
c. Thermal conductivity (W/mK)
d. Frozen
e. Unfrozen
f. Weight of moisture content
g. Correction factor
h. 1. Rock (rock fill, rocky gravel)
   2. Sand and gravel (sandy gravel, rocky moraine)
   3. Silts (quick sand) (powdery moraine, sandy heath)
   4. Clay and mixed soil (moraine containing clay)
   5. Peat

After Gundersen (1976)

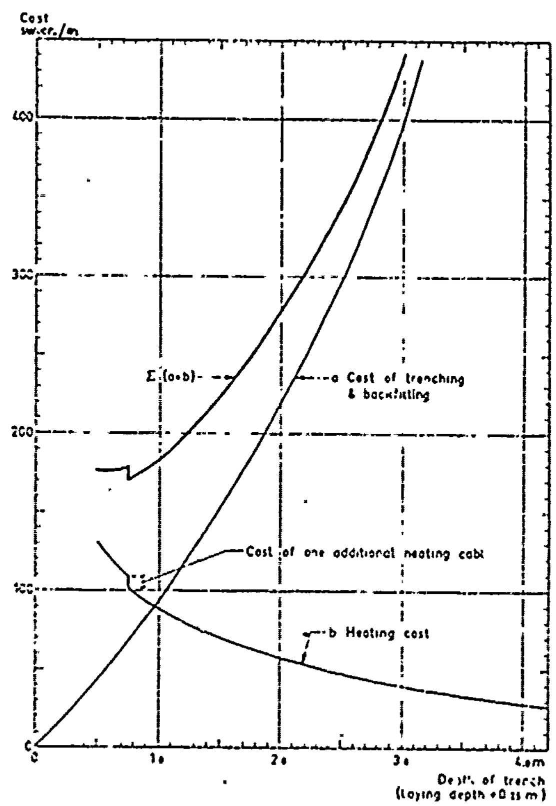

Fig. 1.5: Relation between cost and laying depth in rock. After Janson (1974). Costs are in Swedish crowns (SK_r). The conversion ratio is about SK_r 400 = US \$ 100.

2. Sewage transport systems.

2.1 Scope of work.

During the study trip two groups who are responsible for sewage transport systems were interviewed. These groups were the Thames Water Authority which has the respo[illegible]y for sewage distribution lines from the greater London are[illegible] Electrolux Corporation of Stockholm which manufactures vacuu[illegible]age systems. In addition to these two groups, Professor L.E. Janson o[illegible] the Water Projects Office (VBB) in Stockholm, was also consulted [illegible]ning sewage lines in Sweden.

2.2 Pipe materials and techniques.

Many of the things that pertain to waterlines and were discussed in Part 1 apply equally to Part 2. Plastic, unplasticized polyvinyl chloride (UPVC) and high density polyethylene (HDPE) are finding a very large market in sewage collection lines as well as in water lines.

Recent research in Finland and some of the other Scandinavian countries has pointed out the importance of quality control particularly pertaining to the [illegible] materials used in plastic lines. Another area of concern is manufactured fittings. It was found that the long term behavior of pipe lines is very dependent on the specifications of raw material for both pipes and fittings (L.E. Janson and T. Valinaa, 1974). When plastic lines are used rubber O-rings with slip collars are the standard connection in Sweden and in England (Fig. 2.1). However with high density polyethylene (HDPE) butt welded connections are frequently used. This type of connection is made by heating the ends of the two pipes to slightly under the melting point and then forcing the two ends together under pressure. Conditions, both temperature and pressure, must be carefully controlled, however, properly welded joints have 90% to 100% of the original pipe strength (Fig. 2.2).

As in water systems mentioned above, cast iron lines are largely being replaced with ductile iron. Ductile iron is very competitive in price to cast iron at this time. This is due to a recent change which allows thinner wall ductile iron pipes to be used in many applications. However, there is concern that although the ductile iron is competitive on an initial cost basis with the cast iron, the long term cost will be higher for ductile since it has an estimated life of approximately 50 years compared to gray cast iron's estimated life of 300 years.

Rigid joints are no longer allowed and all joints must be connected with flexible materials, such as the rubber O-ring and slip collars used on plastic. Wall thicknesses for pipe are established according to diameter of the pipe. The rule-of-thumb formula which is used to establish the wall thickness for PVC pipe is: 0.5% of the diameter times the pressure is equal to the wall thickness.

$$t = 0.005\ d\ p$$

where

t = wall thickness (same units as dia.)
d = inside diameter (same units as thickness)
p = pressure ($kg\text{-}cm^{-2}$)

For polyethylene pipe the formula is:

$$t = 0.01 \, d \, p$$

However, due to manufacturing limitations the limit to wall thickness becomes 60 mm, therefore large diameter pipes must be limited in the pressure that they can carry. In Norway pressure sewer lines of 1000 mm diameter are now being manufactured in short and long lengths. A mobile tube extruding machine can produce continuous pipes up to 400 mm O.D. at the site.

In England, brick is still used and preferred by many to other types of piping for very large lines. The largest sewer line in London is 15 ft 6 in. (4.7 m) in diameter. Brick lines have many advantages. They provide better footing for personnel working inside, are easier to repair and last a long time.

Tunneling is used extensively both in Sweden and England. In London, which is situated primarily on a material known as London blue clay, tunneling is done using a large circular cutter which bores its way through the clay allowing workmen to shovel out the muck displaced by the cutter. The tunnels are lined with concrete arch pieces which are fitted together and forced into intimate contact with the tunnel using a wedge member between the top pieces of the tunnel (Fig. 2.3). The boring machine uses the concrete tunnel lining for its footing and forces its way into the material from this footing. Then when the cutting range is used, a new ring of concrete lining arches is installed. The cutting machine now has a new footing upon which to once again forge ahead.

Minitunneling has become very popular for smaller mainlines 1000 mm to 1300 mm diameter. Until the advent of minitunneling these small diameter, smooth bore tunnels were not available. It is often possible to construct pipeline minitunnels at depths of 3 m or less without the disruption of tunneling. A single operator works at the face of the tunnel mucking out the spoil from a cut and a small "mole" is used to carry it away. Figure 2.4 shows the minitunnel system during construction. Figure 2.5 shows various uses for installed minitunnels as electrical utilidors; pipe utilidors etc. More information can be obtained from Minitunnels International Ltd., Westminster House, Old Woking, Surrey, England.

Swedish engineers, particularly in Stockholm, find that tunneling in rock, a technique at which they have become specialists, provides excellent utilidors beneath the city. This was covered in Part 1 on Water Distribution Lines.

2.3 Dual systems.

Most of the larger new systems in Europe use a dual system classification for sewage treatment lines. According to classification this wastewater is either foul water or storm water. Some controversy has developed over this practice. Some argue that the untreated storm sewer water has much higher pollution potential than the treated regular sewage effluent. Therefore, they contend, this water should be treated to the same standards as regular sewage. The opposition points out that this would require the treatment of huge volumes of water and periodic inundation of the treatment facilities. In addition they continue that after the initial flow from a storm has rinsed the streets, succeeding flow contains little contamination.

London deals with this controversy in a unique manner. Storm water is channeled into storm sewers which initially drain to the treatment plants, but during storms (after the initial flow has rinsed the streets) divert to run directly into the Thames River without treatment. Foul water, however, which is composed of raw sewage and industrial wastes, is taken by separate lines to the treatment facilities where it is treated before being dumped into the Thames.

Another variation of this dual systems technique is used by the Electrolux people in Sweden. They divide their wastewater into gray water and black water. The gray water, which consists of wash water and bathing water, is routed from the gray water lines into the toilets where it is reused to become black water. This is then routed to sewage treatment plants. The primary purpose for this does not stem from a lack of water supply, but is merely to provide a means of concentrating the sewage so that minimum volumes need to be treated.

2.4 Vacuum sewage handling systems.

The Electrolux Corporation in Stockholm, Sweden, manufactures components to be used in vacuum sewage treatment systems. The vacuum sewage system has many advantages, among the largest of which is the fact that no trenching or grading of lines is needed. Since trenching composes 80% of the total installation costs of the distribution line, the elimination of the requirement is a large economic advantage. The system works on the technique that sewage is drawn into the lines which are maintained under a constant vacuum. Periodically in the line a low spot is established where the liquid can accumulate into a "slug." Then, whenever a port on the system is opened flow is such that the slugs move from one low point to the next until they arrive at the collection point. This is usually a large tank or the treatment facility. Using this method, lines may go uphill or downhill, following the contours of the ground. In the case of marine installations, lines may be routed between decks without concern that the lines be graded for gravity flow. The components are mostly manufactured of plastics and parts are designed for a lifetime of 25 years.

Electrolux has 25,000 vacuum toilets on the market at the present time. able 2.1 shows present installations in Denmark; 10,000 of these are on shipboard, the other 15,000 in various vacuum systems in small communities around the world, one of which is Norvik, Alaska, which has been reported upon in another CRREL publication (McFadden, in pub.).

The big advantage to the vacuum system for northern aspects is that the lines may be laid on the surface of the ground in small insulated and heated utilidors. In permafrost areas, such as those in Alaska and northern Canada, elimination of the requirement for trenching becomes a significant advantage. Some of the installations in Sweden are in villages of 3,000-4,000 persons. One large system in Germany has 1,000 houses on a single system.

Average transport velocities in the lines are 5-6 m sec^{-1} (16.4-19.7 ft sec^{-1}) with as high as 50 m sec^{-1} (164 ft sec^{-1}) occurring during momentary peaks. The transport pockets (the low areas where the liquid is allowed to accumulate) are spaced 150 ft (50 m) apart, and consist of two 45° elbows. The purpose of these pockets is to allow the vacuum plug to re-form after each flush. These areas contain liquid protected at all times and cannot be allowed to freeze, therefore they must be protected within a heated utilidor.

Some severe climates have caused premature failure of rubber components. In Australia it was found that the abrasiveness of the sand which is carried in the air at this particular installation lowered the lifetime of the rubber seals from 5 years to 2 years. Extreme cold may cause similar problems.

In addition to vacuum collection of sewage, Electrolux is working on vacuum collection of solid wastes; this will be reported on in the next section.

2.5 Inspection systems.

Inspection systems in England make extensive use of the remote T.V. cameras that have been developed by people such as Rees Instruments Limited. These cameras are small diameter (17.3 mm), lightweight, and rugged so they can be fished through large or small lines to inspect for leaks, damage, or obstructions. Figures 2.6 and 2.7 show two typical cameras sold by the above manufacturers. As an alternative to the purchase of these cameras, service companies offer television inspection and testing service. Figure 2.8 from literature by SEER TV Surveys Ltd., Westminster House, Old Woking, Surrey, UK, shows a television picture of a brick sewer tunnel.

2.6 Miscellaneous information.

It was clearly evident that in Scandinavia and the United Kingdom many of the concepts which we have only been discussing in the United States are already being implemented. The black water/gray water concept is an example. This idea has been discussed in the U.S.; however, little real attempt has been made to use it. In England, however, we found it in active use in a number of small projects. Another concept is the use of one trench as a utilidor for multi-purpose pipes (Fig. 2.9). Heating, sewage and water pipes are all placed in the same trench at various depths to preserve the integrity of the lines should a break occur. The heat evolving from the sewage or the heating line makes it possible for a shallower and thus much more economical burial depth to be used. Underground utilidors as built in Alaska have been found to be inordinately expensive, but minitunneling offers a potentially economical alternative.

No.	[illegible]	No. of [illegible]	No. of [illegible]	No. of [illegible] water valves	No. of houses or persons	Year of completion	[illegible]
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[illegible]	" " public inst.	432			432	1973	[illegible]
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110	" "	16[illegible]			169	1973	[illegible]
[illegible]	" "	64			64	1972	[illegible]
112	" " Public inst.	445			445	1973	[illegible], Falster
113	" "	750			750	1972	[illegible]

Table 2.1: Electrolux vacuum sewage system installations in Denmark.

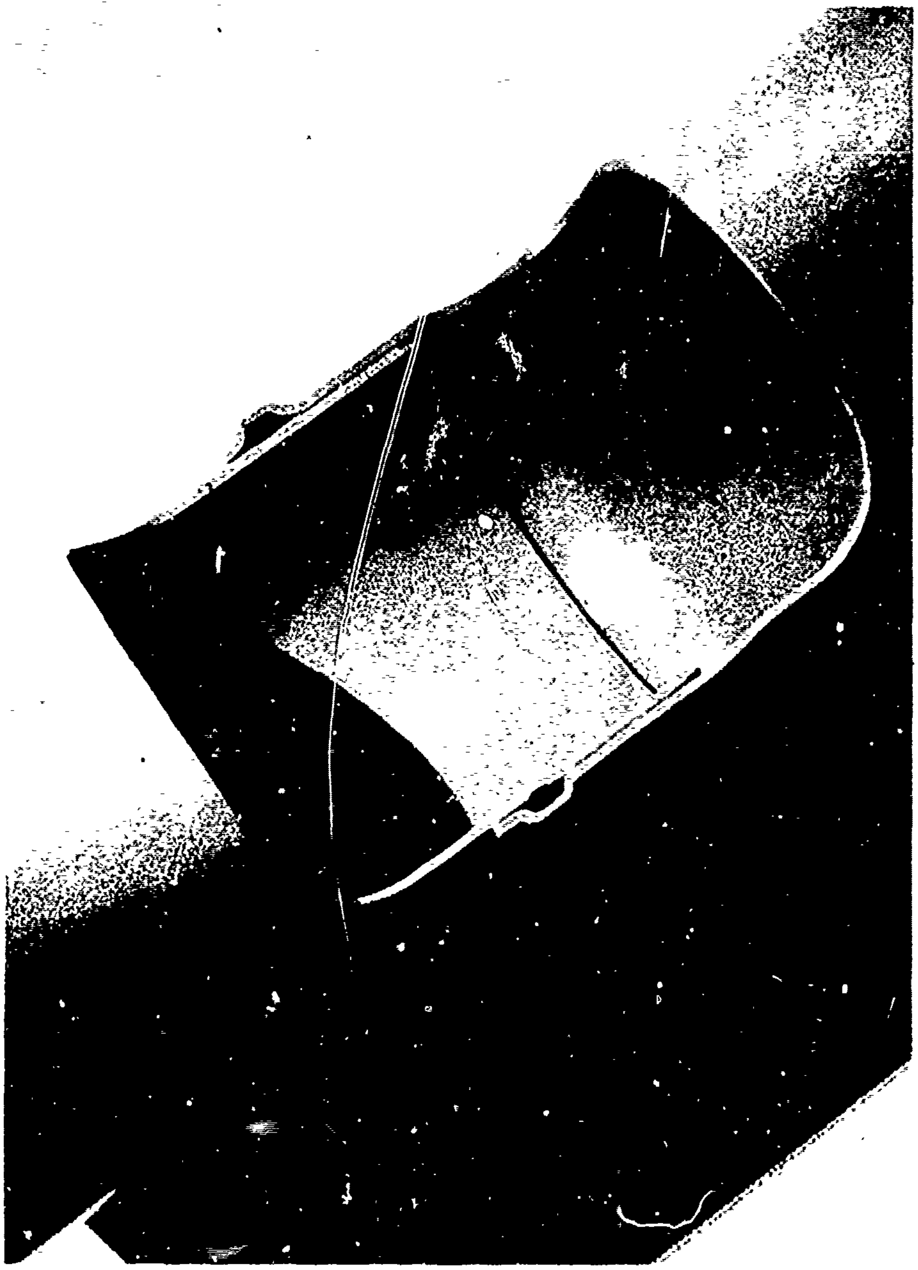


Fig. 2.1: Rubber ring coupling for PVC pipe.

Fig. 2.2: Finished buttweld, welding factor 0.9.

Item	Description		Item	Description	
1.	Shield Shell c/w building clips, ploughs, gland ring		16.	Shield Gravel Hose c/w belled and threaded pipe, gravel gun and clamps	not shown
2.	Thrust Rig c/w rams, shield entry rods, VPM and frame, power pack hydraulic hoses and fittings, air line, floor plate, towing pins and chains, absorption shoes		17.	Shield Track	not shown
			18.	Pit Track	
			19.	Lead Track c/w link bolts	not shown
			20.	Intermediate Rail Track c/w link bolts	
			21.	Air Main c/w couplings	
			22.	Gravel Main c/w couplings	
3.	Front Hood		23.	Air Main c/w coupling	not shown
4.	Rear Hood (upper)		24.	Gravel Main c/w coupling	not shown
5.	Rear Hood (lower)		25.	Pit Air Main Adaptor	
6.	Face Tray Set		26.	Shield Air Main Adaptor	not shown
7.	Clamp Ring		27.	Grout Gun	not shown
8.	Segment Lifting Frame (2 segments)		28.	Shield Entry Frames	
			29.	Mini Mule	
9.	Segment Carriage		30.	Tool Kit	not shown
10.	Transportation Bogie		31.	Air Spade Kit	
11.	Muck Skips c/w load transfer booms		32.	Special Short Shovels	
			33.	Datumlaser (110v)	
12.	Gravel Hopper Loading Skip c/w spare second size mesh		34.	Datumlaser Staff	
			35.	Datumlaser Plinth	
			0/1	Full Face Diaphragm	
13.	Gravel Injection Hopper c/w PVC hose, clamps, gravel and air manifold		0/2	Gravel Hopper Heated insulating jacket	not shown
			0/3	Shield Lifting Bridle	not shown
			0/4	Face Board Ring	
14.	Gravel Injector		0/5	Shield Propping Blocks	
15.	Pit Gravel Hose c/w belled and threaded pipes and clamps		0/6	Blast Screen	

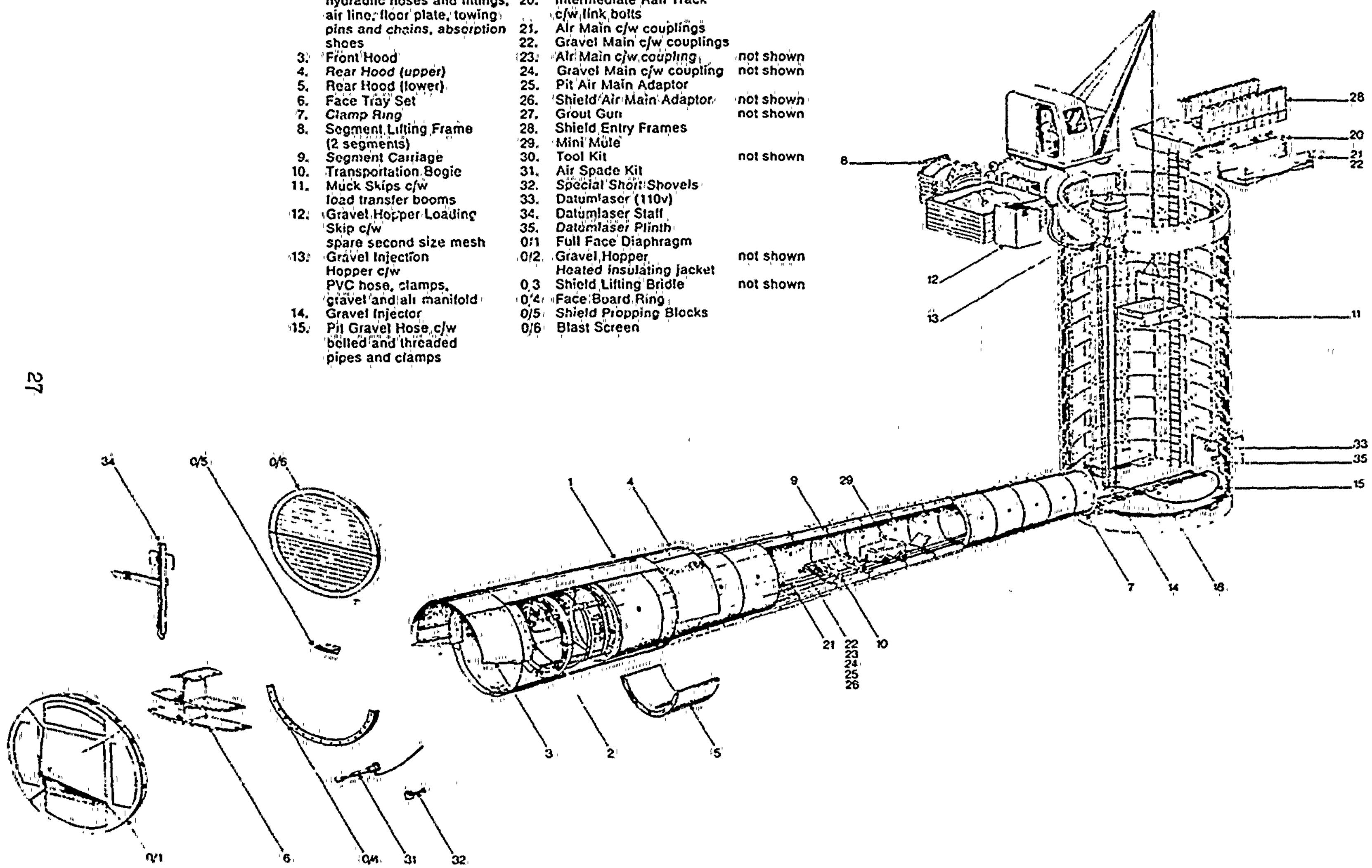


Fig. 2.4: Minitunnel system during construction.

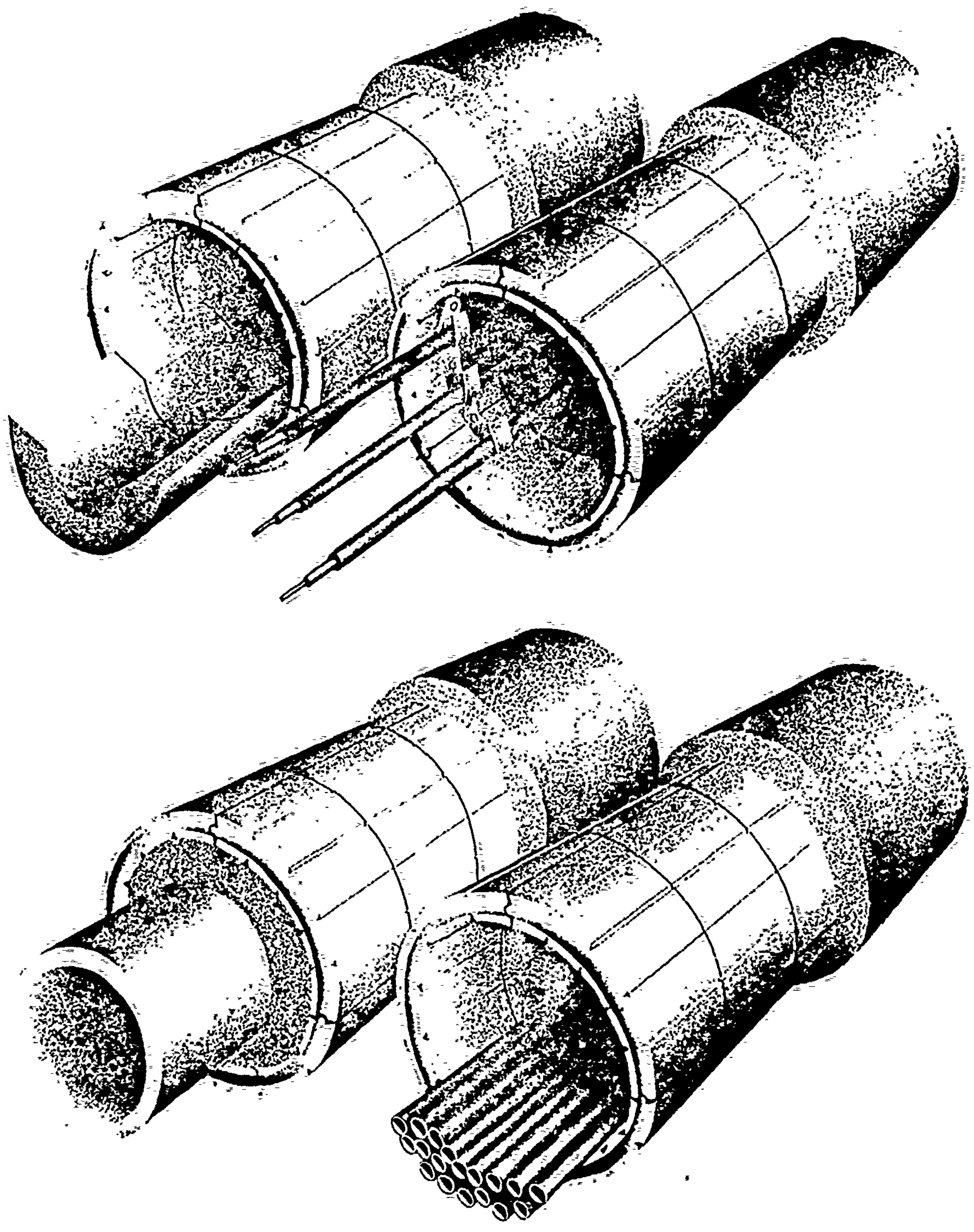
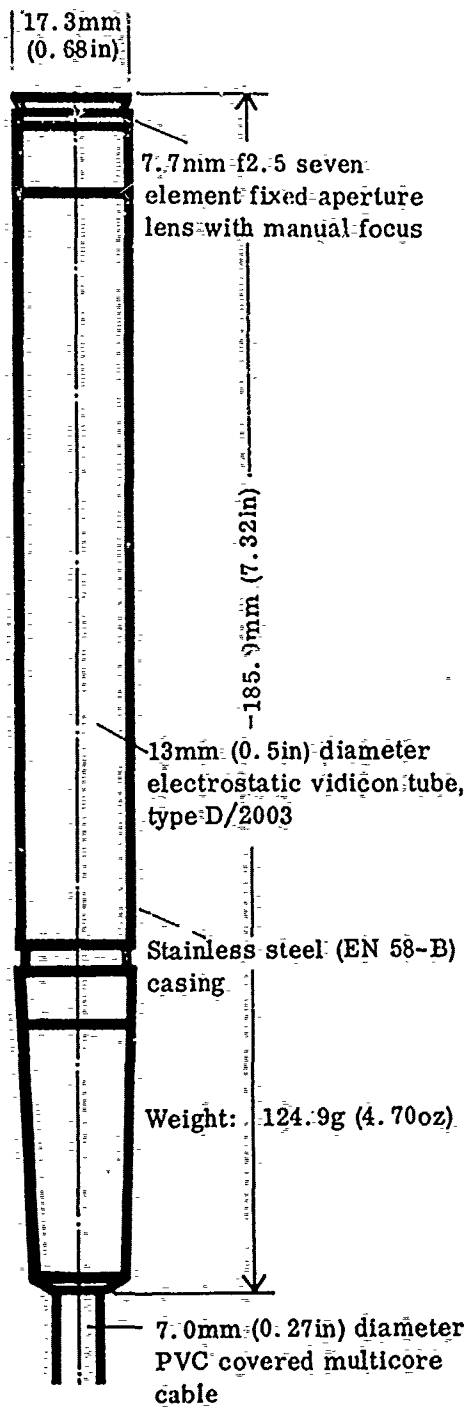


Fig. 2.5: Minitunnel uses for different utility needs.

Rees 20 cctv Camera System



The Rees 20 camera was originally developed to facilitate the internal inspection of small condenser tubes in nuclear power stations. Its small size and impressive picture quality have since enabled engineers to inspect other small cavities, ducts and piping, previously inaccessible to cctv cameras.

SPECIFICATION

Performance (utilising vidicon tube type D/2003)

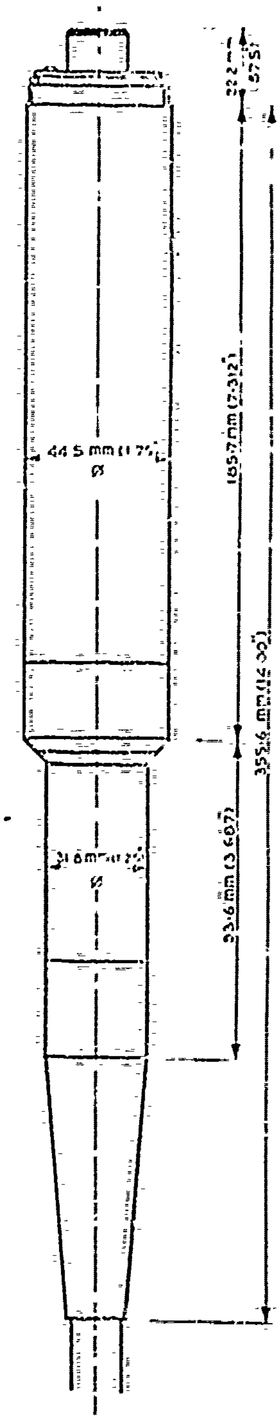
Resolution:	Horizontal centre 400 tv lines using standard 7.7mm lens
Scanning Rate:	625 lines. 50 field/s crystal interlace on 50 Hz supply
Power Supply:	110/240 volts 50Hz 15VA or DC Supply.
Sensitivity:	Scene illumination of only 35 lux at source gives a usable picture. Auto light compensation - 4000:1
Linearity/ Distortion:	Point deviation from true position is within 3% of picture height.

Operating Environment

Temperature: -10°C to +50°C (14°F to 122°F)

Fig. 2.6: Typical T.V. inspection camera.

Rees 80 (Otter) series
Rees 80 cctv camera



SPECIFICATION

Diameter	:	44.5mm (1.75in)
Length	:	393.6mm (15.5in) including 80/01 view head and cable gland 524.6mm (20.65in) including 80/02 view head and cable gland 504.8mm (19.88in) including 80/03 view head and cable gland
Weight	:	1.0Kg (2.2lbs) including 80/01 view head and cable connector
Materials	:	Camera body, view heads and cable connectors are all constructed of SN—58B (321) stainless steel
Optics	:	6.5mm f2.5 five-element fixed aperture coated lens
Angle of view	:	52° diagonal in DRY environment
Depth of focus	:	1cm to infinity

Performance (utilising vidicon tube type 9738/2. 13mm (0.5in diameter)

Resolution	:	Horizontal centre 300 tv lines using standard 6.5mm lens (Marconi resolution chart No-1)
Scanning rate	:	625 lines, 50 field/s random interlace on 50 Hz supply 525 lines, 60 field/s random interlace on 60 Hz supply
Sensitivity	:	10:1 signal to noise ratio picture obtained using 6.5mm lens with a a scene illumination of 250 lux at source. Scene illumination of only 50 lux at source gives a usable picture. Auto light compensation — 4000 : 1
Linearity/ Distortion	:	Point deviation from true position is within 3% of picture height.

Operating Environment

Temperature	:	−10°C to +55°C
Underwater depth	:	136 metres (450ft)
Underwater pressure	:	1.519 MN/m² (15 atmospheres)
Radiation	:	10^7 R gamma total absorbed dose.

Rees Instruments Ltd. Westminster House,
Old Woking, Surrey, GU22 9LF, UK.
Telephone: 048-62-61317 Telex: 859679
Cables: Rees Woking.
A Rees Group Company

Fig. 2.7: Typical T.V. inspection camera.

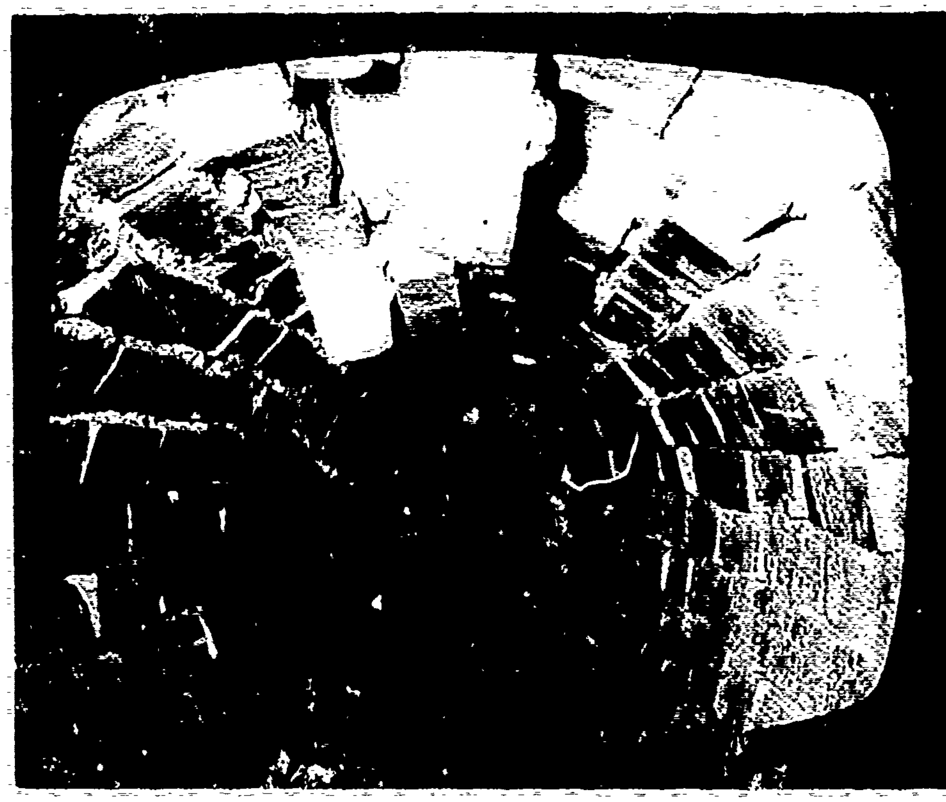


Fig. 2.8: T.V. inspection of brick sewer line.

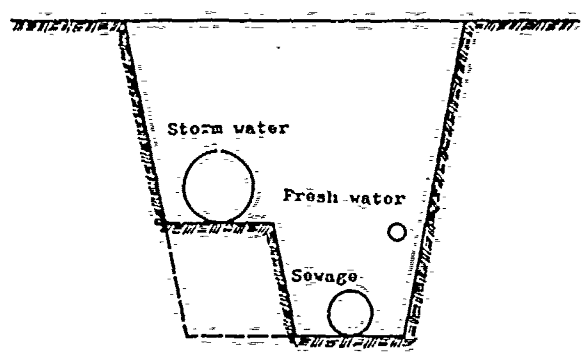


Fig. 2.9: Single trench with multi lines.

3. <u>Solid waste collection system</u>.

Solid waste collection in Europe is done in much the same manner as it is in this country. More and more use is made of this waste as a fuel for energy generation. One large heating plant in Malmoe, Sweden, is entirely fueled by solid waste.

Discussions were with personnel of the heating plant of the Lisson Green Development in London which has a pneumatic refuse collection system with incineration boiler.

This solid waste collection system is in the Marylebone district of London. While the system is not unique in Europe (there are also applications in the U.S.) it did represent the state-of-the-art and was in operation and fully functional. (Most of the U.S. systems are still in the installation stage.)

The system consists of a 20-inch pneumatic tube which connects the 1500-apartment complex to the collection facility (Fig. 3.1). The apartment buildings have collection bins in which residents can deposit their solid wastes. Bins are periodically opened to the vacuum line allowing the wastes to be transported to the collection center where they are segregated and the combustible portions are used to fire a hot water boiler. It supplements 3 oil fired boilers (Fig. 3.2). The heat generated by the boilers is used for heating the apartment complexes.

The system has several advantages. Since it is completely closed, all vermin and rodents are eliminated. Odors are kept to a minimum. Segregation of the burnables and non-burnables is largely done with the use of a cyclone separator which effectively sorts light from heavy materials. Light materials are predominantly burnable trash whereas the heavy materials with little additional handling are sent to the local sanitary landfill. The personnel maintaining and operating the system have reported very little difficulty.

Air velocities in the tubes during the collection phase are in the neighborhood of 60 mph (27 m sec^{-1}) and no problems have been encounter d thus far with plugging of the large main tube. Noise is considered somewhat of a disadvantage; however, watching a sample cycle we found the noise to be little more than would be normally encountered from a team of garbage men working through the neighborhood collecting the garbage.

The overall system was most impressive. A convenient disposal chute was located within a few steps of virtually every apartment in the complex. Collection was controlled from the central facility and collection cycles are timed to be in periods when noise levels encountered during collection are acceptable. Interlocks prevent the doors on the individual depository chute from opening during the collection phase so that there is no possibility of unwanted material being sucked into the collection chute. The system is manufactured by a Swedish firm and is now being marketed in the U.S.

One disadvantage is that the collection system and incinerator plant must necessarily be in the immediate vicinity of the apartment complex since long distance transportation of the solid waste is not feasible. The esthetics of the large diameter pipe might also be considered objectionable by some, as might the boiler stacks. However, in this particular installation we found the system to be well designed and esthetically far from displeasing (see Fig. 3.1). The stacks emitted no objectionable smoke while we were in the vicinity. Since the incinerator is part of a boiler plant, this disadvantage was turned to an advantage. The heat from the incineration boiler supplements the oil-burning boilers (Fig. 3.2) for district heating.

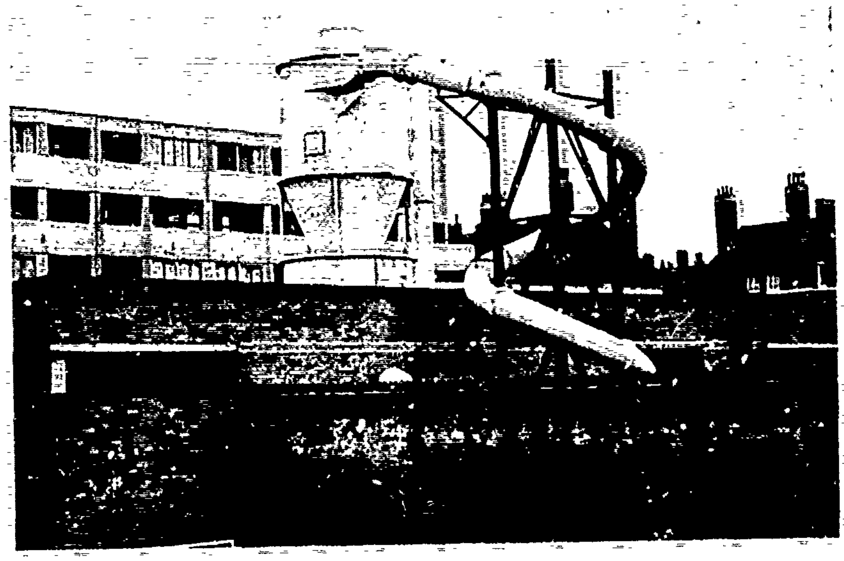


Fig. 3.1: Collection pipes and cyclone separator

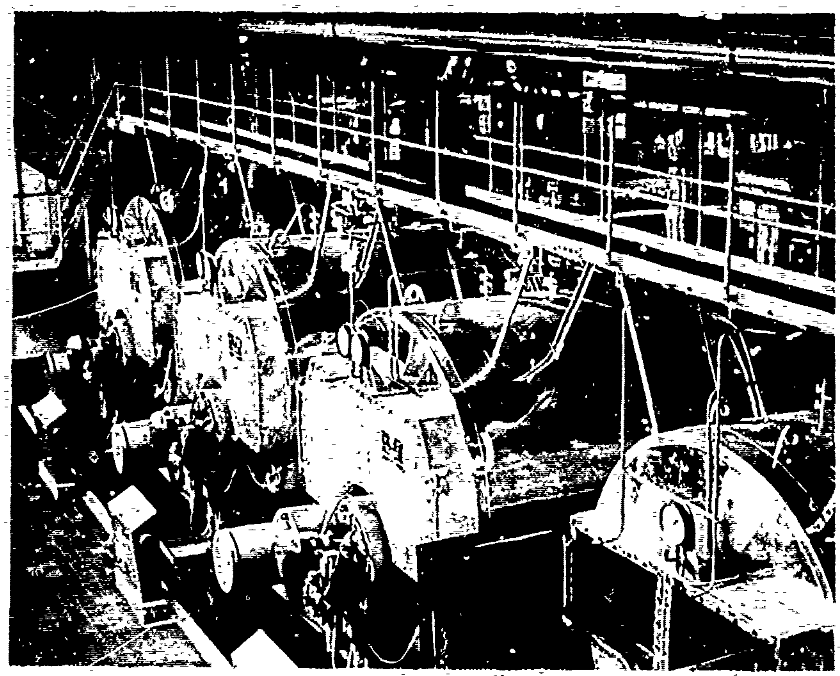


Fig. 3.2: Oil fired district heating boilers.

4. Electric transmission and distribution.

The principal subjects discussed with personnel of the Sydkraft Electricity Authority in Sweden and the Norwegian Research Institute of Electricity Supply (EFI) and the Norwegian Water Resources and Electricity Board, State Power System (NVE-S) were the icing of transmission lines and the use of self-supporting aerial cables for distribution. Related information was obtained from the Helsinki Electricity Works in Finland by correspondence. Other subjects discussed with personnel of the Association of Norwegian Power Plants (Samkjoringen av Kraftverkene i Norge) and the London Electricity Board were large area network links, hydropower reservoir management and wholesale trade. Some Norwegian information was obtained on the galloping of power lines.

4.1 Icing of transmission lines.

Icing is mainly a problem in Norway, to a lesser extent in Sweden. A paper by Tron Horn (Heavy Ice and Snow Loads on Conductors and Towers in the Mountain Districts of Norway, CIGRE Meeting, International Study Committee No. 6, Paris, 6 June 1964) reports on observed icing conditions and shows impressive pictures. Figures 4.1.1 and 4.1.2 are taken from his report. Ice build-up of 0.9 to 1.4 m around 15-mm conductors occurred. Transmission lines have to be built to connect radio and TV transmitter stations on mountain tops to facilities below. Some are designed to withstand forces as high as 200 kg/m ice load combined with 35 kg/m wind load. The experience shows that when the direction of the transmission line is perpendicular to the prevailing wind direction and the surrounding terrain gives no protection, large ice loads may be expected. When the line is parallel to the wind direction, heavy icing on the conductors is not normally experienced even when the surrounding terrain gives no protection; however, towers will experience heavy icing.

E. Olaussen (Icing on Overhead Lines in Norway, January 1974, the Norwegian Research Institute of Electricity Supply (EFI), Technical Report No. 1829, Trondheim, 22 June 1974) reports on conditions experienced over a large area in Norway during a prolonged storm and cites good correlation with observations at the ice load test station of the Norwegian Water Resources and Electricity Board, State Power System (NVE-S) near Lillehammer. The usefulness of meteorological information for prediction of icing is indicated.

The first step towards protection against ice damage is in the design of the line. A meteorological evaluation is made of the proposed route. In critical areas the evaluation will analyze every tower location individually. In some places the plans for tower locations will be changed to avoid unnecessarily severe conditions. Thereafter, the problem is straightforward structural design for the predicted conditions.

The second means for protection is during actual icing conditions. The lines are operated at full capacity, if necessary using a dummy load. This is usually sufficient to prevent icing, but is not always possible, particularly on large capacity lines.

Ice can be removed from wires by pulling a hook or a wire loop over the wires. Another method is to a tap the wires with wooden poles.

Another winter problem with transmission lines is that towers on slopes have been found to be deformed by lateral snow forces. These forces are much greater than the hydrostatic overburden forces due to lateral restraint (arch effect) within the snow. Design criteria for tower bases are being revised to allow for such situations.

4.2 Galloping of transmission lines.

This problem is observed in Norway. It is also a problem in the United States. A paper by Th. Bednar, Chief Engineer, Oslo Light Company, OLV (Vibrations of Power Lines, Elektro-teknisk Tidsskrift, Vol. 81, No. 4, 22 February 1968) discusses observations at a mountain test station with two 122-m spans. The lines swung with a circular cross section motion. The circle was observed to have a diameter of 3.20 m and tensile forces, measured with a dynamometer, were 10.8 tons, compared with a normal tension of 3.2 tons. At another site, forces as high as 14 tons were recorded. Sometimes the motion was a deformed circle due to the wind pressure and sometimes the motion was strictly vertical, as with so-called galloping. A paper by G.S. Wilton, T.S. Ormiston and Z.A. Allan, South of Scotland Electricity Board (Modern Transmission-Line Maintenance) Proc. IEE, Vol. 114, No. 7, 1967) discusses problems encountered with galloping of 275-kV lines in Scotland and England.

A paper by M. Ervik, T. Horn and R. Johnsen (Erection of and Vibration Protection on Long Fjord Crossings in Norway, International Conference on Large High Tension Electric Systems, CIGRE, Paris, 10-20 June 1968) discusses methods of vibration damping. The summary of the paper is as follows:

In Norway more than 100 fjord-crossings with lengths over 1000 m are in operation. During the last 5 years 8 fjord-crossings for 275 kV with lengths varying from 1400 to 4570 m were installed. The use of 4 phases, one of which is a spare one, of individual towers for each phase, which have a height of 10 to 25 m only, is significant. A description is given of the older method and recent methods for the erection of fjord-spans. The recent methods use basically a specially equipped vessel. The methods are illustrated with figures. Data for the 8 fjord-crossings and their conductors are given.

Fjord-crossings are more exposed to vibration than common overhead line spans. Equipment for vibration measurement, its use and the evaluation of measurements, are described. Examples of vibrations damping results achieved on long spans are given together with information about the damping equipment and experience with it.

Norwegian standards for mechanical dimensioning and construction of electric overhead lines (NEN 11.2.65) cover mechanical load conditions such as ice load, wind load, temperature variations, cable weight, non-symmetrical load, elevation differences and horizontal angles, one-sided tension forces and dynamic stresses.

4.3 Self-supporting aerial cables.

Self-supporting aerial cables are lightweight multi-conductor cables consisting of three or four spiral wrapped, insulated conductors with no outer jacket and without a separate mechanical support wire. The aluminum conductors provide the mechanical strength as well as electrical conduction. These cables are rapidly gaining popularity in Finland, Sweden and Norway for distribution up to 24 kV because they offer lower cost installation and greater reliability than bare overhead wires.

Finland started the development in Northern Europe. The standard product is the AMKA cable (Fig. 4.3.1) which has three insulated and one bare neutral supporting conductor. Rated voltage is 750 V. Construction details and electrical properties are given in Tables 4.3.1 and 4.3.2, taken from AMKA Self-Supporting Aerial Cable; K. Matikainen, J. Mörsky, S. Patja, O. Pirinen and R. Särmäntö; SÄHKÖ-Electricity in Finland, Vol. March 1972, No. 3.

Sweden developed the ALUS cable with all conductors insulated (Fig. 4.3.2). Available sizes are 4 x 25 mm^2 and 4 x 50 mm^2 for 1 kV rating and 24 kV rating with other sizes expected to become available.

Norway has EX and EXW cables shown in Figure 4.3.3 a-b (Figures of cable cross sections are taken from the Norwegian Research Institute of Electricity Supply (EFI), Newsbrochure No. 4, Vol. 14, December 1974 with article by Thor J. Hafstad). Type EX is available from 2 x 16 mm^2 to 3 x 95 mm^2, EXW up to 3 x 150 mm^2 with 16 mm^2 steel cable.

Appendix 4.1 gives illustrations of LIDON accessories and installation practices for ALUS cables. The cables can be hung from poles with either insulated or uninsulated hangers. The use of shear pins permits the cables to drop under excessive load to prevent line rupture and service interruption.

The main advantages of self-supporting aerial cables are:

a) Lower cost than bare overhead wires.

b) Greater reliability than bare overhead wires, approaching that of underground cables.

c) No need for clearing of a right-of-way through woods except to cut branches which rest and rub on the cable.

d) Less aesthetic disturbance than bare overhead wires.

e) Greater opportunity to use poles for multiple purposes.

f) Less line reactance and lightning susceptibility.

4.4 Power lines and energy trade.

In England there are 12 areas for electricity supply. They operate and are interconnected by a system of 132 kV transmission lines. Within each area there are 66 kV and 33 kV main substations and 11 kV substations for further distribution. In London all electrical distribution is underground.

The Electricity Council consists of the chairmen of the 12 Area Boards and the chairman of the Central Electric Generating Board (CEGB). It advises the Government. Capital comes from the Government, rates are set by the Government and wages are influenced by the Government.

The Scandinavian countries are interconnected by a large high-voltage transmission network as shown in Figure 4.4.1. There is extensive electric energy track between the countries, related to the regional availability of hydroelectric power. Norway has very large hydroelectric resources and is a net exporter of electricity.

The Scandinavian network is a 50 Hz system, as also is the continental European system. However, it is not in phase with the continent. Therefore, interties with the continent are by direct current (DC) cable. Western Denmark is part of the continent. It is electrically separate from eastern Denmark which is linked with Sweden. There is an existing 250 kV DC line (260 MW) between Sweden and western Denmark, the only link between Scandinavia and the continent. Another link is planned for 1976 and 1977 between Norway and Denmark. It is also 250 kV DC with a capacity of 2 x 250 MW. The technical difficulty with the construction of this link is the deep trench off the coast of Norway which has depths over 600 m (nearly 2000 ft) and is 130 km long.

High voltage transmission lines such as 275 kV and 380 kV are usually built in Norway with twin conductors. The cost is about $120,000 per km or about $200,000 per mile. The cost of cables is 15 to 20 times greater than the cost of overhead lines.

In all Scandinavia every effort is made to place distribution lines underground. This applies primarily to urban areas, of course. Methods for cost effective laying of cables are sought but novel methods have not been found. In unpaved areas, e.g., along highways approaching cities, where lighting is being installed, a method of plowing cables into the ground is being used successfully. This method is also used in the United States.

In Norway, essentially all power plants are hydroelectric. There is an Association of Norwegian Power Plants which plans and coordinates the electrical production of the plants and the export-import trade. For this purpose an electric energy market exchange is conducted. Every week each producer submits his offer to supply an amount of energy and his price. This offer is influenced by the producer's reservoir condition, anticipated water supply conditions and anticipated market conditions. The offers are then combined to give a supply picture.

Next, the demand is estimated based on experience factors and a wholesale price is set which matches the amount offered at prices up to that wholesale price. Thus, a market is made. Other considerations which affect the wholesale price are related to the export (or import) market. This is influenced by the price of electricity in other countries (e.g., Sweden with about 24% thermal power) which usually favors export. Reservoir management at the national level in anticipation of future market condiions is also considered.

Table 4.3.1. **Details of the construction of AMKA cables.**

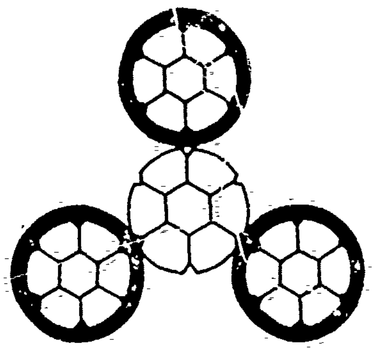
AMKA (number and cross sectional area of conductors)	Insulated conductors					Neutral messenger			Total cable		Delivery	
	Number and cross sectional area	Number of strands in conductor	Diameter of conductor max.	Metal mass	Insulation thickness	Number of strands in conductor	Diameter max	Metal mass	Diameter max.	Total mass	Standard production length	Type of reel
mm²	mm²		mm	kg/km	mm		mm	kg/km	mm	kg/km	m	
1 × 16 + 25	1 × 16	1	4.55	50	1.4	7	6.1	70	14.5	140	1,000	D
1 × 25 + 35	1 × 25	7	6.1	70	1.4	7	7.2	100	17.5	190	1,000	D
1 × 35 + 50	1 × 35	7	7.2	100	1.6	7	8.6	140	20.5	270	1,000	E
3 × 16 + 25	3 × 16	1	4.55	130	1.4	7	6.1	70	19.0	270	1,000	D
3 × 25 + 35	3 × 25	7	6.1	210	1.4	7	7.2	100	23.0	390	1,000	D
3 × 35 + 50	3 × 35	7	7.2	290	1.6	7	8.6	140	26.5	540	1,000	E
3 × 50 + 70	3 × 50	7	8.6	410	1.6	7	10.4	190	30.0	740	1,000	F
3 × 70 + 95	3 × 70	7	10.4	580	1.8	7	12.0	260	36.0	990	1,000	F

Table 4.3.2. **Electrical properties of AMKA self-supporting cables.**

AMKA	D.c. resistances Ω/km				Inductive reactance at 50 Hz	Max. permissible current capacity	Rated current of overload protection	Max. permissible short-circuit current lasting 1 s	Insulation resistances at +60 °C, minimum
	phase conductors		neutral conductor						
mm²	+20 °C	+65 °C	+20 °C	+65 °C	Ω/km/phase	A	A	kA	MΩ/km
1 × 16 + 25	1.894	2.237	1.380	1.597	0.083	75	63	1	306
1 × 25 + 35	1.212	1.431	0.986	1.141	0.081	100	80	1.5	242
1 × 35 + 50	0.866	1.025	0.690	0.799	0.080	125	100	2	236
3 × 16 + 25	1.894	2.237	1.380	1.597	0.110	70	50	1	306
3 × 25 + 35	1.212	1.431	0.986	1.141	0.106	95	63	1.5	242
3 × 35 + 50	0.866	1.025	0.690	0.799	0.104	115	80	2	236
3 × 50 + 70	0.606	0.716	0.493	0.571	0.101	140	100	3	202
3 × 70 + 95	0.433	0.511	0.363	0.420	0.098	180	125	4	193

Figure 4.1.1.: Ice loads on the conductors of a 20-kV line located 1300 m above sea level in southern Norway. The maximum measured ice load is 302 kg/m.

Figure 4.1.2.: Dead end tower of a 20-kV transmission line, 1666 m above sea level. In the ice on the upper part of the tower a transformer has been operated without difficulties.



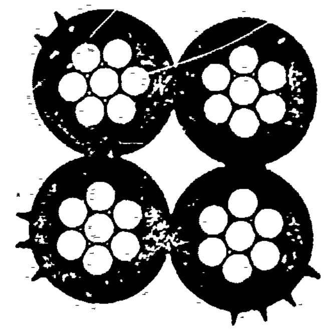
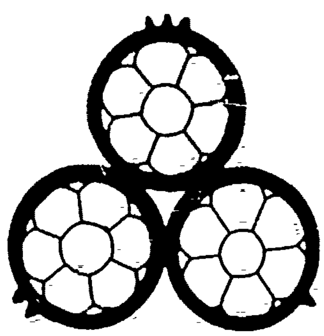


Figure 4.3.1.: Cross section of Finnish AMKA self-supporting aerial cable.
Figure 4.3.2.: Cross section of Swedish ALUS self-supporting aerial cable.



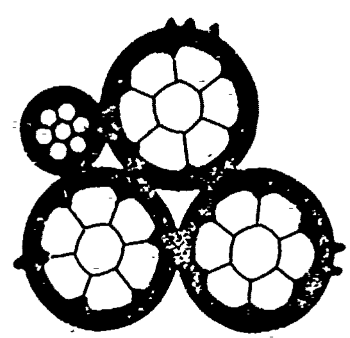


Figure 4.3.3.a and 4.3.3b: Cross section of Norwegian self-supporting aerial cables types EX and EXW.

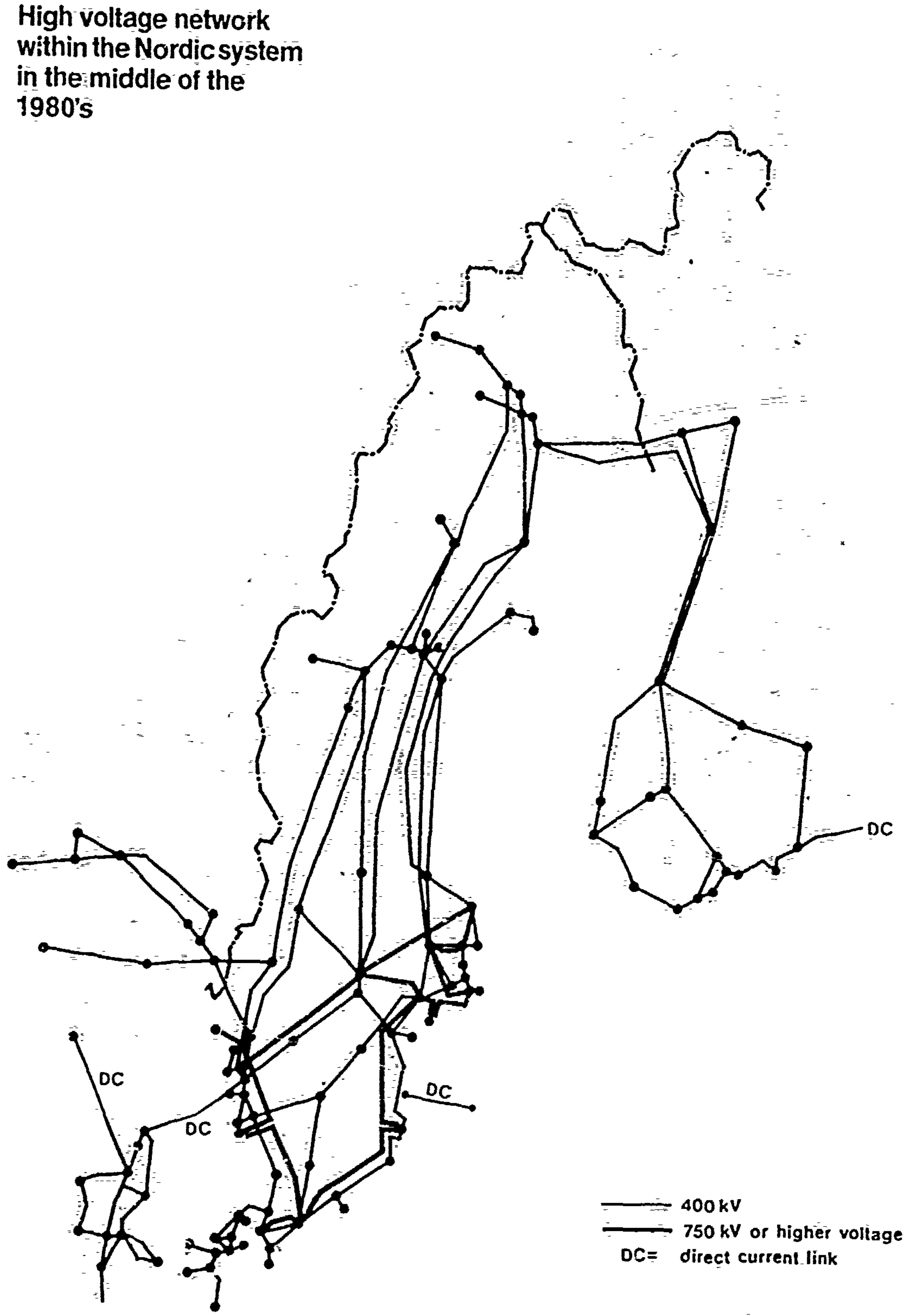


Figure 4.4.1.: The Scandinavian high-voltage transmission system (from 1972 Study by CDL - Central Operating Management, Sweden).

Appendix 4.1. LIDON accessories and installation practices for ALUS self-supporting aerial cables.

LILJEHOLMENS kabel

LIDON

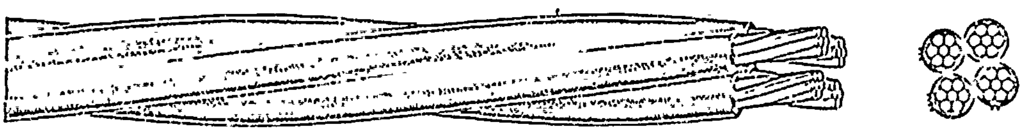
Tillbehör till självbärande hängspiralledning typ ALUS

februari 1971

Distributionssystem med självbärande hängspiralledning

ALUS

Självbärande hängspiralledning typ ALUS är utvecklad för lågspänningsdistribution som ett ekonomiskt konkurrenskraftigt alternativ till friledning och hangkabel typ AKKD. Den rekommenderas bl a av VAST-Vattenfall. Ledningen har två eller flera symmetriskt hopslagna parter med 25 eller 50 mm² area. Ledarmaterialet är olegerad aluminium och isoleringen svart polyeten. Märkspänning 1 kV.

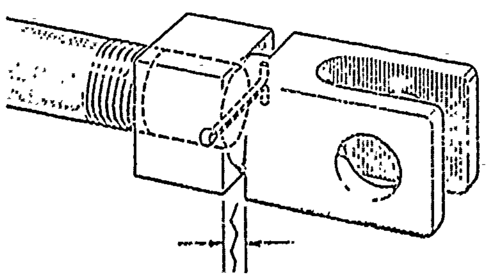


Parterna är märkta med åsar. Obs att det är antalet mellanrum mellan åsarna som avgör partens nummer. Man kan både se och känna detta.

LIDON

LIDON är samlingsnamnet på Liljeholmens Kabels tillbehör för hängspiralledning. Med LIDON-produkterna uppfylls kravet på ett lättmonterat, funktionssäkert system. LIDON-produkterna är utprovade under lång tid och uppfyller bl a VAST-Vattenfalls senaste fordringar (jan 1971).

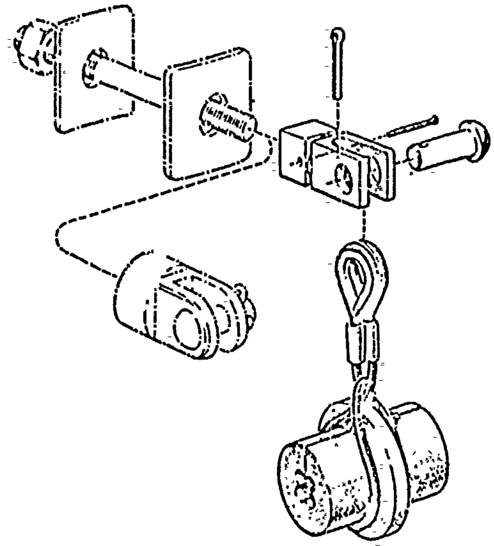
PINNSKRUV 3/4"



Gaffelsäkring

Gaffelsäkring S 25 och S 50 är tillverkad av varmförzinkat stål. Den är avsedd att skruvas på pinnbulten tills saxsprinten stoppar. Gaffelsäkringen har en avsiktlig försvagning som gör att den brister innan påkänningen på ALUS-ledningen överskrider tillåtet värde.

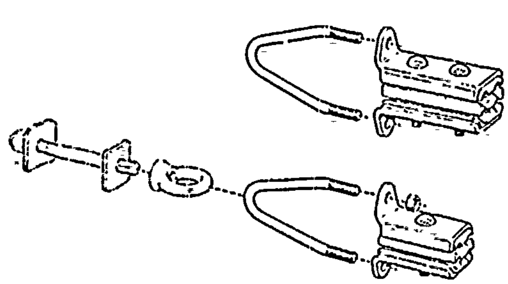
ALUS area mm²	LIDON typnr	beskrivning	löser ut vid kN	SEG-nummer
4X25	S 25	gaffelsäkring	ca 4	
4X50	S 50	gaffelsäkring	ca 6	



Hängfäste

Hängfäste HS 25 och HS 50 består av stålstropp klädd med högvärdig plast och manschett av väderbeständigt gummi. Hängfästet är skonsamt mot hängspiralledningen och lätt att montera. Hängfästet används vid raklinjestolpar och vid vinkelstolpar upp till 30°.

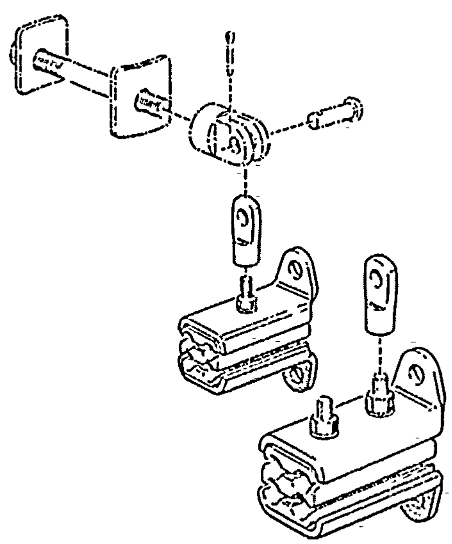
ALUS area mm²	LIDON typnr	beskrivning	SEG-nummer
4×25	HS 25	stålstropp + gummimanschett	
4×50	HS 50	stålstropp + gummimanschett	



Spännfäste

Spännfäste AS 25 och AS 50 består av backar av hård PVC som är infästa i varmförzinkade ståldetaljer. Spännfästet används tillsammans med bygel av varmförzinkat stål vid vinkelstolpar över 30°, ändstolpar och avgreningar.

ALUS area mm²	LIDON typnr	beskrivning	SEG-nummer
4×25	AS 25	spännfäste	
4×25	BY 25	bygel	
4×50	AS 50	spännfäste	
4×50	BY 50	bygel	

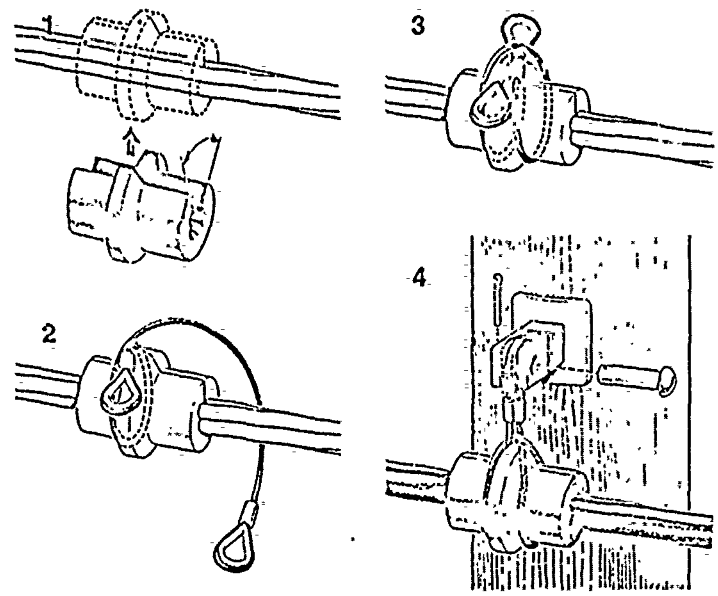


Förstärkt hängfäste

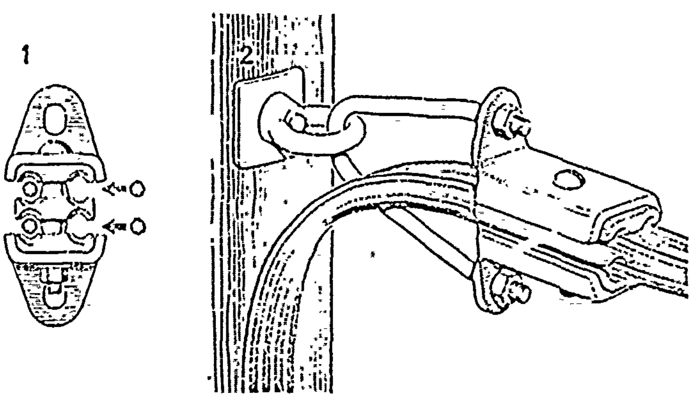
Spännfäste AS 25 och AS 50 tillsammans med ögla av varmförzinkat stål kan krävas vid t ex korsningar där praktiskt ingen glidning i fästet tolereras.

ALUS area mm²	LIDON typnr	beskrivning	SEG-nummer
4×25	AS 25	spännfäste	
4×25	Ö 25	ögla	
4×50	AS 50	spännfäste	
4×50	Ö 50	ögla	

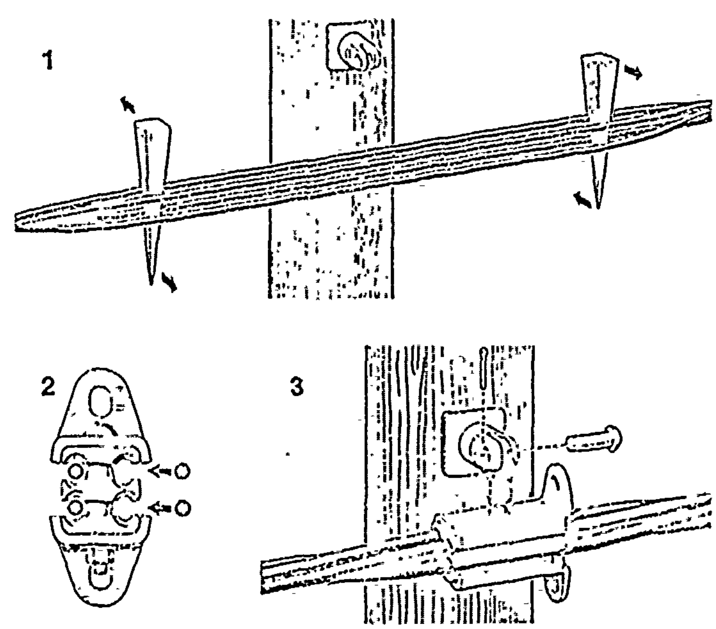
Montering
ALUS-parterna skiljs inte åt vid monteringen. Med ett enkelt handgrepp träs manschetten över ledningen. Obs att manschettens öppning alltid skall vara uppåt och att stålstroppen fästes med dubbelt halvslag.
Stroppens båda öglor fästs i gaffelsäkringen med bulten som spärras med saxsprinten.



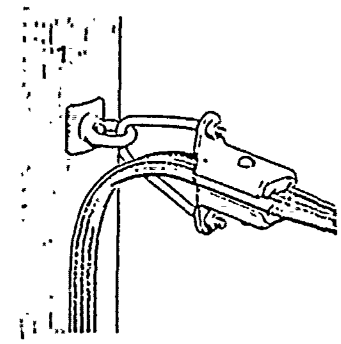
Montering
Backarna säras så mycket att parterna kan skjutas in två från vardera sidan. Muttern lossas ej från bulten. Parterna skall ligga i spåren i hela donets längd när muttern dras åt. Muttern dras kraftigt. Lämplig skiftnyckel storlek 10.
När ledningen hängts upp justeras nedhängningen genom växelvis åtdragning av bygelns muttrar.
Monteras spännfästet på sträckt ledning används kilar för att sära parterna. Se nedan.

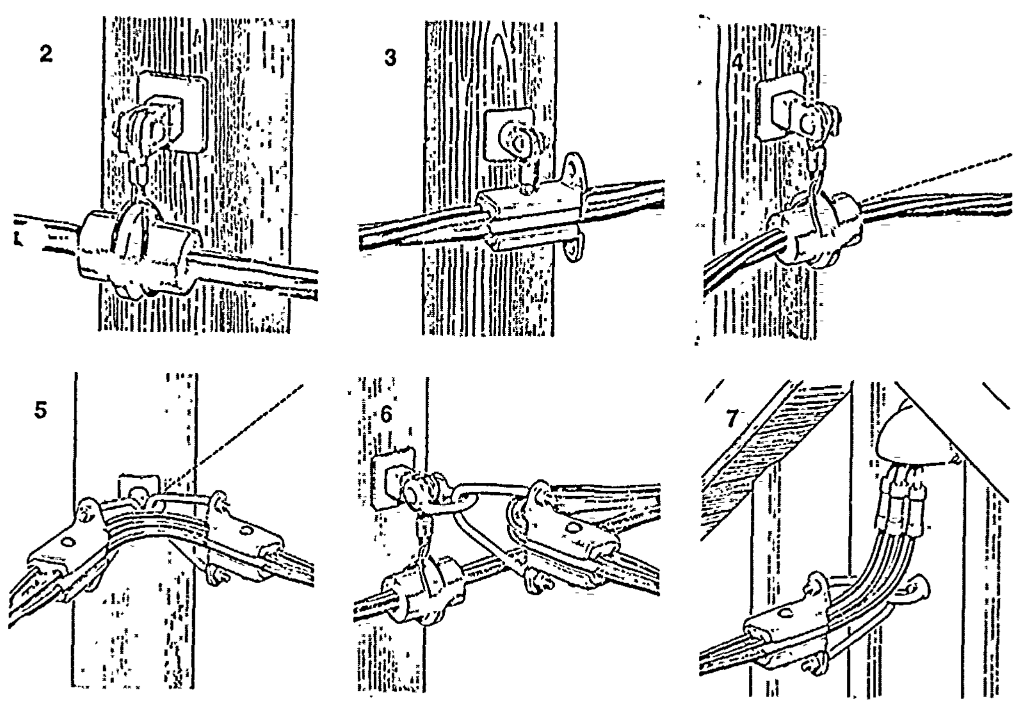


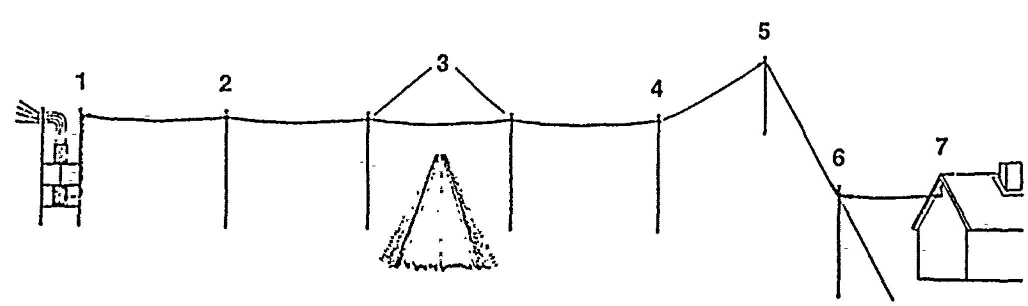
Montering
Parterna säras med hjälp av kilar. Monteringen av fästet på ledningen sker som ovan. Öglan skruvas på den genom fästet gående bulten och fästs därefter i gaffelhuvudet.



Principskisserna visar kraftdistribution vid lågspänning med ledning ALUS och LIDON-systemet. I punkterna 1, 5, 6 (avgreningen) och 7 tolereras praktiskt ingen glidning, varför LIDON typ AS används. I exemplen 2, 4 och 6 (genomgående linjen) monteras LIDON typ HS. I punkt 3 används antingen AS eller HS.







Kontakta närmaste ASEA-SKANDIA-filial eller Liljeholmens Kabel för närmare upplysningar om LIDON-tillbehören.

5. <u>Heat distribution.</u>

Most of the discussion of heat distribution were in Sweden with personnel of the Swedish District Heating Association (VVF), the Stockholm Energy Works, the Södertörns District Heating Authority, and the Malmoe Industrial Works. In England, discussions were with personnel of the District Heating Association, including its founder Mr. Haseler, and with the London Electricity Board. From Finland, information was obtained by correspondence with Mr. Kilpinen, Chief Engineer of the district heating department of Helsinki Electricity Works.

The basic difference between the methods of heat distribution used in Europe and those used in the United States is the carrier medium. In Europe hot water is used in contrast to steam which predominates in U.S. systems. Distribution lines in Europe are insulated pipes in ducts (culverts) or directly buried, but essentially always underground, similar to U.S. practice. Differences are usually related to the characteristics of water compared with steam.

Information on heat distribution in permafrost areas is essentially unavailable. This is not really surprising since even in North America there are only a few systems on permafrost; they are small and mostly on military installations.

The subjects discussed in this chapter are various pipe insulation systems, the efficiency of heat distribution, and costs.

5.1. Insulated pipe systems.

A paper by Risto Vartia of the Helsinki Electricity Works on the Planning and Construction of District Heating Pipelines gives a comprehensive description of the designs and materials used in Finland. It is included for reference in Appendix 5.1.1.

One of the insulations described in R. Vartia's paper as jackets is an insulated culvert produced by Fiskars. It is finding increasing use because it offers an economical method for heating pipeline installation. It is used for direct burial. Details are described in Appendix 5.1.2.

Examples of typical current Swedish pipe installation and insulation practice are given in Figures 5.1.1. through 5.1.8. Large pipes ranging in size from 250 mm (about 10 in.) to 700 mm (about 28 in.) inside diameter are installed in ducts (culverts) as shown in Figure 5.1.1. Generally, cast-in-place ducts seem to be preferred because they offer the best water tightness. A drain tile under the duct adds to the water protection and sumps, with access for pumping, are provided at low points. Glass wool or mineral wool insulation is placed around the pipes. Outer jackets are not applied so that moisture can always escape, however, a plastic sheet is often used to cover the top half of the pipe over the insulation for protection against the possibility of water dripping on the pipes. Vent stacks are also installed at intervals as shown in Figure 5.1.2. They permit humidity to escape from the duct. They are used also for forced drying, when necessary. For that purpose compressed air is blown into one vent stack. The escaping air on adjacent stacks shows telltale condensed vapor plumes until the duct is dry.

A variation of the insulation system described above is to fill the duct with cellular concrete instead of wrapping glass wool insulation around the pipes. Vent and drainage channels are provided in the corners of the duct. Views of pipes being installed in ducts are shown in Figures 5.1.3. and 5.1.4.

Smaller pipes are installed in the pipe-in-pipe systems with air gap as shown in Figure 5.1.5. Sizes from 125 mm (about 5 in) to 300 mm (about 12 in.) inside diameter are installed individually within a pipe, smaller sizes from 25 mm (about 1 in.) to 100 mm (about 4 in.) inside diameter are installed in pairs within a pipe. Figure 5.1.6. and Table 5.1.1. give additional detail information about these pipe-in-pipe systems. The hot water pipes are steel tubes joined by welding. The spacer for positioning the pipe (slightly above the center of the outer pipe) is polyurethane foam and the insulation, 20 to 40 mm thick, is glass, mineral wool or polyurethane foam. The outer pipe is steel, polyurethane or asbestos cement coupled with O-ring seals. Asbestos cement will be prohibited in Sweden from 1978 on because of reports that show that it may be carcinogenic. The royal Swedish labor protection board has decided that asbestos cement should be replaced by less dangerous materials.

Some use is made of steel, plastic or copper tubes with mineral wool or urethane foam insulation and extruded polyethylene or PVC jacket. Joints are covered and sealed with plastic heat-shrinkable sleeves. These directly buried pipes come in all dimensions and are used for service lines. They provide an economical method of installation. Figures 5.1.7 and 5.1.8 show examples of such installations.

A development coming from Germany offers increased efficiency and simplicity of installation for small pipe sizes. The pipe with its integral insulation and protective jacket is flexible and can be buried directly in long continuous lengths, following curves and slopes similar to an electrical cable. Figure 5.1.9 illustrates the installation method. Connections are made with standard fittings. The inner pipe is made of corrugated copper or stainless steel tubing. The insulation is foamed polyurethane rated at 120°C. The outer pipe is corrugated steel with extruded polyethylene jacket. Figure 5.1.10 shows details of this "cable-pipe."

Another development from Sweden is copper tube with glass wool insulation and extruded HD polyethylene jacket (Appendix 5.1.3.). In small diameter sizes the pipe is supplied in large coils with 25-m lengths. Larger sizes come in straight lengths. The pipe is buried directly in the ground in a slightly sinusoidal line which eliminates the need for expansion compensation. The copper tube expands and contracts inside its jacket. Joints are soldered and insulated and sealed with a heat-shrink sleeve.

Thermal movement of heat distribution pipes is compensated by two basic methods: Expansion loops and bellows. An example of an expansion loop is shown in Figure 5.1.11 for a large pipe size. Loops are a very reliable method for movement compensation. Bellows are used as far as possible in distribution systems and avoided in others. Alignment of the pipe ends at the bellows connection is critical, otherwise the bellows fail prematurely. Stress corrosion sometimes also causes failure.

"No Comp" patented compensation - free method of heat distribution pipe installation has found some application in Sweden. The pipes are installed, heated to a prescribed temperature and anchored such that the operational temperature changes produce stresses that are within the code limits. The pipes are restrained by anchors and frictional forces. The principle is similar to the continuous welded steel rails which have found wide application by railroads around the world.

5.2 Distribution methods and efficiency.

For distribution of hot water from the plant to an urban area a closed circuit primary distribution system with supply and return lines is used. Examples of networks for primary distribution are shown in Figures 5.2.1. and 5.2.3. A network may be supplied by several plants; small and growing networks may be linked to a larger existing network, and neighboring networks may be interconnected. Large networks, supplied by different plants, offer increased reliability and economic feasibility. Figure 5.2.2 shows the energy balance for the supply and the sale of district heat in Helsinki. Note the combination of heat and power plants, heating plants and also one refuse incineration plant.

The supply temperature in the primary distribution varies between 70 to 80°C and 120°C, depending on the weather. The highest supply temperature is delivered during the lowest ambient air temperature at the location (e.g. -20°C) and the lowest supply temperature is delivered at about +2 to +4°C ambient air temperature and above. Figure 5.2.4 illustrates in principle the water temperatures and flow rates as related to the weather. The flow rate is essentially constant at the rated capacity and the water temperature is modulated corresponding to the heating requirements. The return water temperature depends on the efficiency of the customers' heat exchangers and varies about as shown in Figure 5.2.4. Low return temperatures are encouraged through rates based on the amount of water used and with thermostat controlled flow valves at the return pipe connection.

The service lines connecting the main distribution lines to individual buildings are linked to heat exchangers within the buildings for secondary distribution. The secondary distribution supply system temperature is usually in the temperature range of 60 (return) to 80°C (supply) (140 to 176°F). Pressures in the secondary distribution are low, as in common hot water heating systems with oil burning boilers.

The separation of primary and secondary water systems provides protection to the building from the high pressures of the primary system and protection to the primary system from problems in secondary systems. The heat exchangers are compact pieces of equipment taking the place of a boiler. Figure 5.2.5 shows the principle of a building connection.

A typical heat exchanger for a large building is shown in Figure 5.2.6. This "consumer substation" may serve a building with many apartments or offices or even a residential area with separate individual homes. For individual homes the alternative is an individual "substation" as shown in Figure 5.2.7. The heat exchanger with controls is a package unit resembling an appliance that may be set up in the basement or the kitchen. Such package units make it economically feasible to connect many small consumers individually to the primary distribution system.

When district heating is introduced in a new area removed from an existing distribution system, mobile heating plants are moved into the area to supply the growing network. Figure 5.2.8 shows mobile heating plants. After two to three years, when construction of a main supply line from the big distribution system is feasible, the mobile plant is disconnected and moved to the next site. Isolated distribution systems supplied by transportable plants are shown in Figure 5.2.1.

Distribution to low density areas is more costly than to high density areas. Therefore, central city areas are usually served by district heating first. As a system grows, the marginal cost of adding subscribers diminishes and it becomes feasible to supply lower density areas at the perimeter of a city. Sometimes a small community can be served economically when it is located close to a main transmission line. The possibilities for low density distribution are illustrated by the example of the city of Västerås in Sweden, where 98% of the heating needs are supplied by district heating. The population is about 100,000, not counting about 20,000 inhabitants in suburbs. The connected load was 848 MW(th) in March 1976 and heat deliveries were 1657 GWh(th) per year. The distribution system included 342 km of pipes from 80 to 1000 mm diameter and 170 km of pipes less than 80 mm.

In central Stockholm the connected values of district heating load in March 1976 was 1267 MW(th) with deliveries of 1946 GWh(th) through 168 km of pipes, 50 mm diameter or greater. The corresponding load density is about 125 MW(th)/km^2. The quoted lower load density limit for economical operations is 15 to 20 MW/km^2. By comparison, the electric load density in the central city is 160 MW(e)/km^2 and in the suburbs about 2 MW(e)/km^2. The high electric load density in the city is probably due to heavy use by industry and public transportation. It should be noted that the heating load density of a suburb is usually several times greater than the electric load density. Therefore, district heating is approaching economic feasibility in suburbs.

The heat losses from district heating are 5 to 6% in high density areas, 15 to 20% in low density areas, about 8% average for Sweden. The fluid dynamic friction losses which must be offset by pumping power are estimated to be about 5%. (Fluid friction losses are not lost thermal energy but become part of the delivered heat!) By comparison, electrical transmission and distribution losses are about 12 to 13%.

The design load capacity of various pipe sizes is summarized in Table 5.2.1. Small pipes are operated at lower water velocities than larger pipes to avoid excessive fluid friction losses.

5.3 Distribution costs and benefits.

District heating can be economical only when most buildings in an area to be served subscribe to the service. This is the same situation as with municipal water and sewage systems. A law concerning district heating will take effect in autumn 1976. This law says that when an area is designed for district heating everyone has to use district heating.

The requirement may appear undesirable or inequitable. However, the experience proves the contrary. Rates for district heat are set such that it is less expensive than the heating cost with self-owned oil burning equipment. District heat is also more reliable, requires less maintenance, and is safer. Therefore, everybody is anxious to get district heating service.

Rates for district heat in Stockholm are listed below the reference. They include a basic subscription fee, a distribution fee, a cost of living index fee and a production fee.

a) Subscription fee

C-	100 kW	500 Skr/year+50 Skr/kW/year
100-	1000 kW	2500 Skr/year+30 Skr/kW/year
1000-	3000 kW	12500 Skr/year+20 Skr/kW/year
3000-	10000 kW	27500 Skr/year+15 Skr/kW/year
10000-	30000 kW	77500 Skr/year+10 Skr/kW/year
over	30000 kW	227500 Skr/year+ 5 Skr/kW/year

b) Distribution fee

0.50 Skr per m^3 hotwater that cirkel through the subscribers receiver.

c) Cost of index fee

$$\frac{K-350}{350}(a+b)$$

a = subscription fee b = distribution fee K = consumer price index of the middle month in the preceding quarter

d) Production fee

1,285 x R öre per kWh

Where R = special reference price

The relative shares of the four fees making up the cost of district heat were in 1973 about as follows:

Subscription fee	16%
Distribution fee	22%
Cost of living index fee	5%
Production fee	57%

The average heating cost to the customer in 1973 was SKr 0.0376/kWh(th), of which SKr 0.0133/kWh(th) were distribution costs. For comparison, the average cost of electricity (mostly hydroelectric) was SKr 0.0951/kWh(e), of which about SKr 0.033/kWh(e) represented distribution costs. The average cost for district heat was about SKr 7.00 per square meter (10.76 ft^2) of living space. Prices for 1974 and 1975 are significantly higher, due to higher oil prices.

The exchange rate at the end of 1973 was SKr 4.60 = US$ 1.- . In 1975 the rate is about SKr 4.- = US$ 1.-.

The cost of the distribution system in Stockholm is about SKr 200 per kW(th). The cost of installing pipes as shown in Figure 5.1.5 is given by the following relationship:

Cost in SKr/m = 500 + 5 D

whereby D is the diameter (inside) in mm. This is the installed cost in suburban areas. In central cities the cost is 50 to 100% higher.

The charges for a subscriber connection to the system depend on the particular situation. Specific rates are given. When an area becomes designated for district heating service, the customers in the area are given a credit for their existing heating equipment, depending on its size and age, if the conversion is made during a specified one-year period.

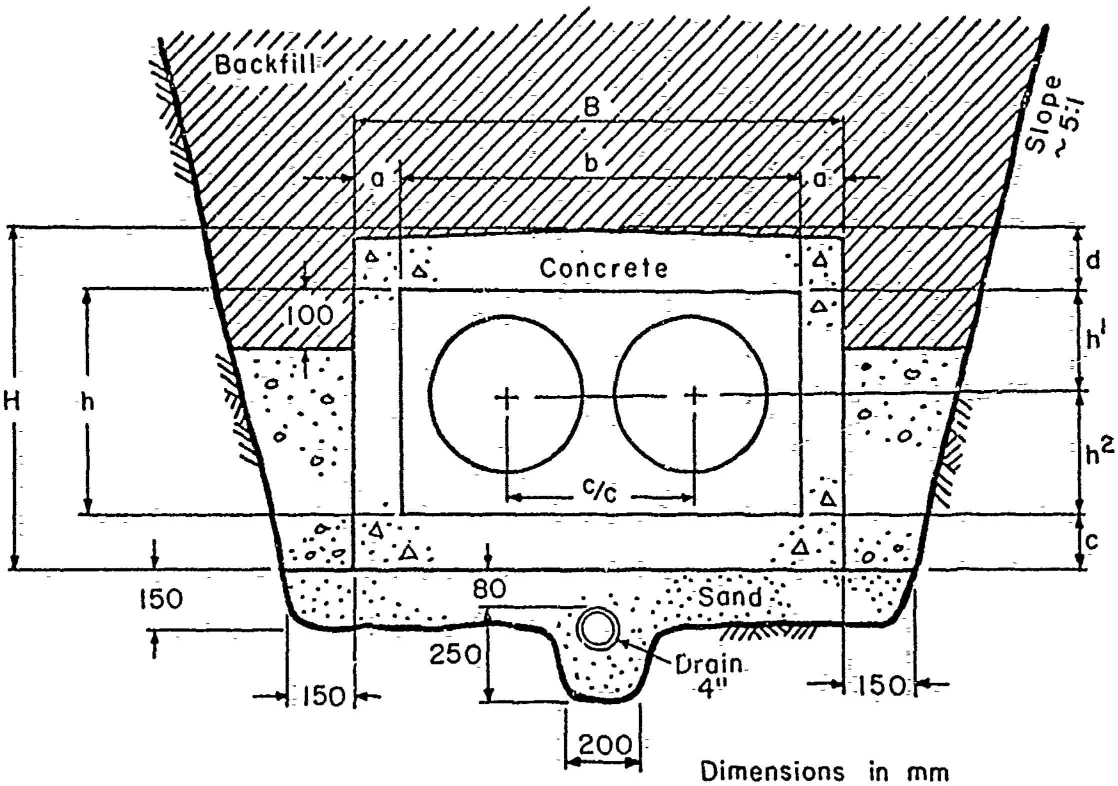
One of the big benefits of district heating is the clean air that prevails in the city, compared with the pollution of cities without or before district heating.

Culvert Type	2x25/200	2x32/200	2x40/200	2x50/250	2x65/300	2x80/300	2x100/350	1x125/250	1x150/250	1x200/300	1x250/400	1x300/450
Steel Pipe	2x25	2x32	2x40	2x50	2x65	2x80	2x100	1x125	1x150	1x200	1x250	1x300
∅ Dy	33.7	42.4	48.3	60.3	76.1	88.9	114.3	139.7	168.3	219.1	273.0	323.9
c/c Supply and Return Line	95	95	95	120	145	130	150	420	420	470	600	650
Asbestos Cement Pipe												
Inside Dia.	200	200	200	250	300	300	350	250	250	300	400	450
Outside Dia.	226	226	226	280	334	334	384	280	280	334	442	496
Pipe spacer of polyurethane foam												
ha	105	105	105	130	155	155	180	130	130	155	205	
hb	77	77	77	102	127	127	152	102	102	127	177	
Di	37	46	52	63	79	92	120	143.5	175	225	280	340
Dy	192	192	192	242	292	292	342	242	242	292	392	443
c/c	95	95	95	120	145	130	150					
Insulation in Asbestos Cement Pipe												
Inside Dia.	33.7	42.4	48.3	60.3	76.1	88.9	114.3	139.7	168.3	219.1	273	324
Thickness	20	20	20	20	30	30	30	30	30	30	40	40
f	---	---	---	---	---	10	15	---	---	---	---	---
Insulation in Buildings												
Thickness	60	60	60	60	60	80	80	40+60	40+60	40+60	60+60	50+60
Capacity with a Supply-Return at =50°C												
m^3/h		1.5	2.4	5.2	12.7	18	28	44	62	115	175	
m/sec		0.5	0.6	0.7	0.9	1	1	1	1	1	1	
Press. Drop mmH_2O/m		8	9	11.2	12.0	11.0	8.5	6.6	5.3	3.6	2.8	
Mcal/h	35	75	120	260	635	900	1400	2200	3100	5750	8750	
m^3/h						36	56	88	124	225	350	
m/sec						2	2	2	2	2	2	
Press. Drop mmH_2O/m						40	31	24	19	13.2	10.5	
Mcal/h						1800	2800	4400	6200	11250	11250	

Table 5.1.1: Dimensions of insulated hot water steel pipes in asbestos cement pipes (in millimeters).

Table 5.2.1.: Water velocities and thermal carrying capacities of hot water pipe lines.

Pipe inside diameter mm	Water velocity m/s	Capacity ($\Delta T = 55°C$) MW(th)
32	0.9	0.2
40	1.0	0.3
50	1.2	0.6
65	1.4	1.2
80	1.6	1.9
100	1.8	3.6
125	2.0	6.1
150	2.2	9.8
200	2.5	20
300	2.7	45
400	2.8	75
500	2.9	125
600	3.0	190
700	3.0	260
800	3.0	340
900	3.0	430
1000	3.0	530
1100	3.0	640
1200	3.0	760
1300	3.0	890
1400	3.0	1030
1500	3.0	1180



Type	Tube Dia	C/C	b	B	a	h	H	c	d	h1	h2
2.5	250	350	780	1020	120	480	750	150	120	245	235
3	300	400	880	1120	120	530	800	150	120	280	250
3.5	350	440	950	1190	120	550	840	160	130	265	285
4	400	528	1080	1320	120	595	915	170	150	320	275
5	500	630	1280	1580	150	745	1085	180	160	420	325
6	600	732	1490	1790	150	850	1220	200	170	475	375
7	700	834	1780	2080	150	990	1360	200	170	560	430

Figure 5.1.1.: Typical Swedish water pipe installation in ducts for pir sizes of 250 mm (10 inches) and greater.

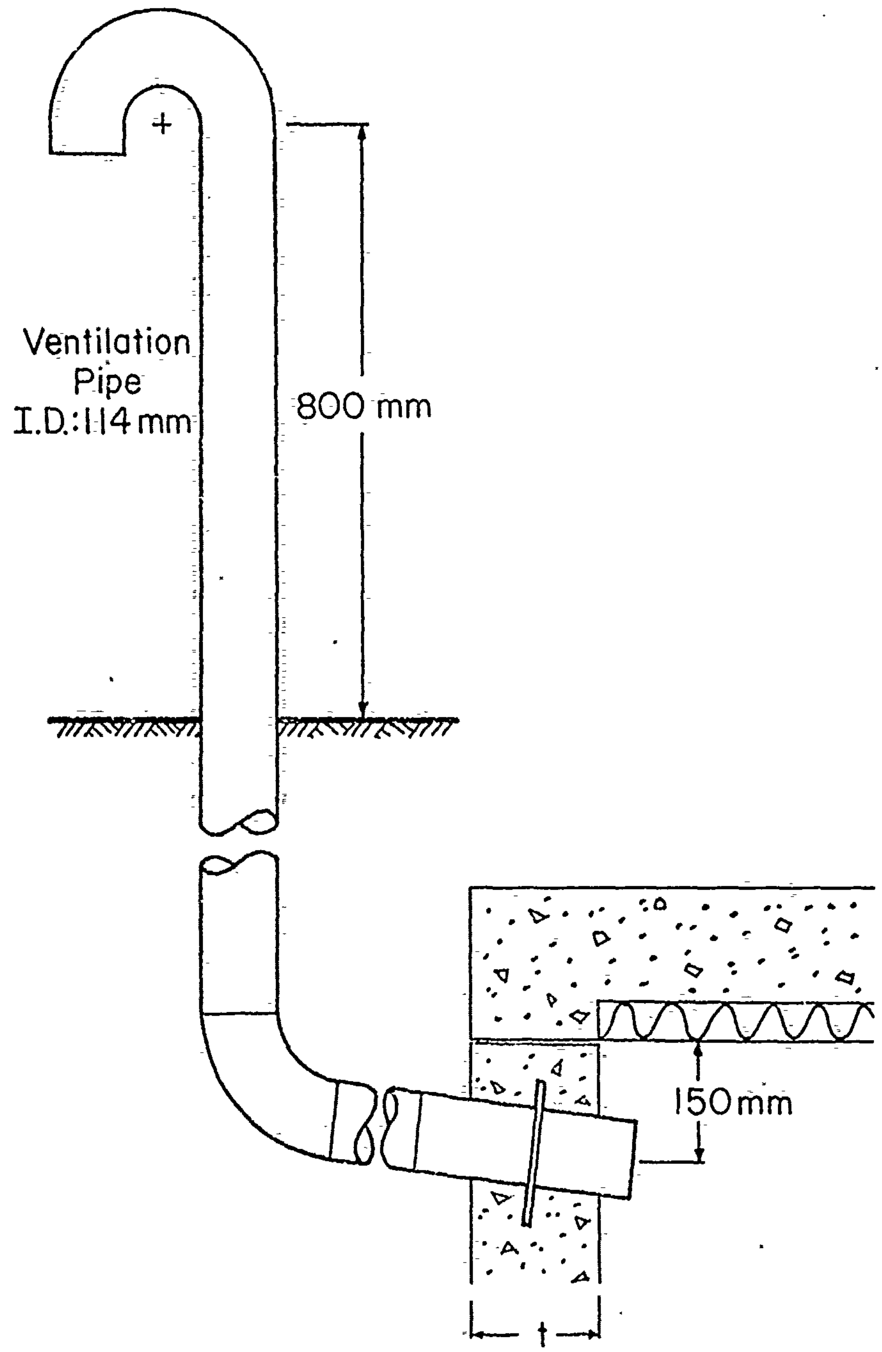


Figure 5.1.2.: Detail of a typical duct vent for natural and forced drying of ducts and pipe insulation.

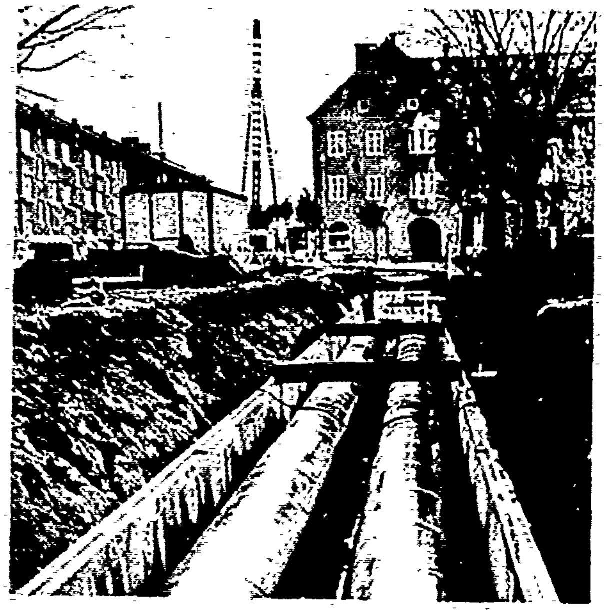


Figure 5.1.3: Installation of 800-mm pipes in Malmoe, Sweden.

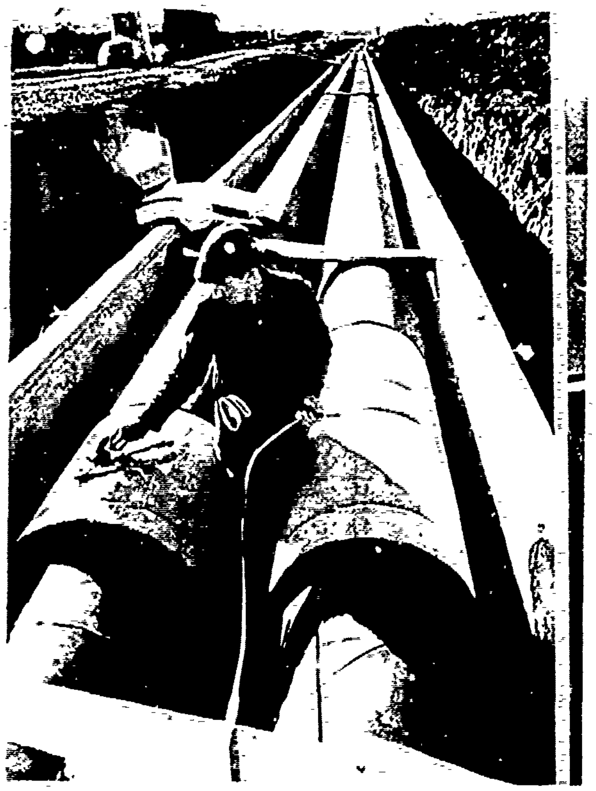
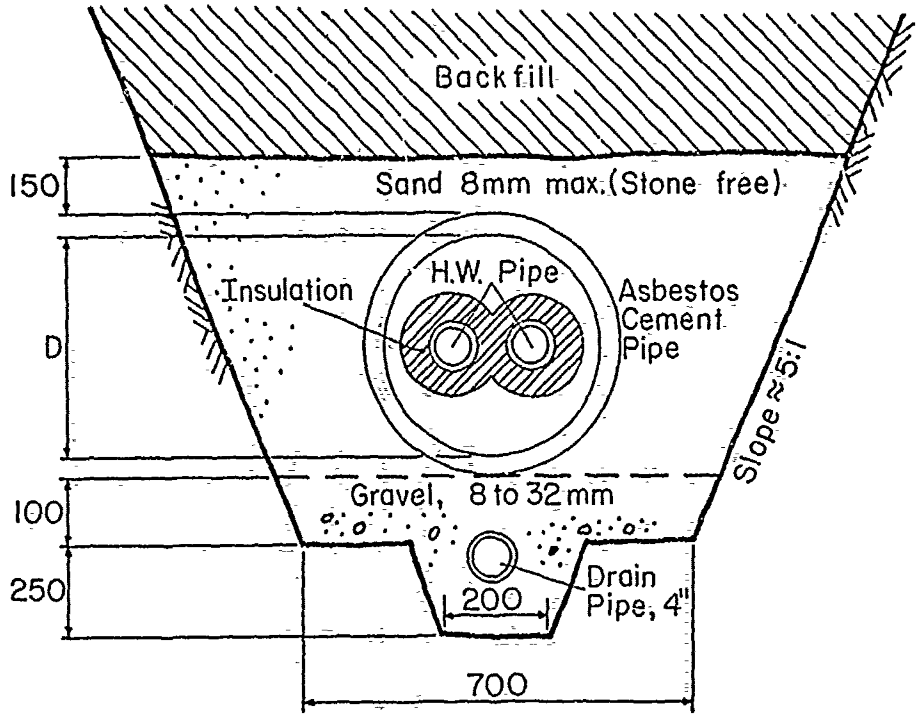


Figure 5.1.4: Application of mineral wool insulation to hot water transmission mains in Stockholm, Sweden.



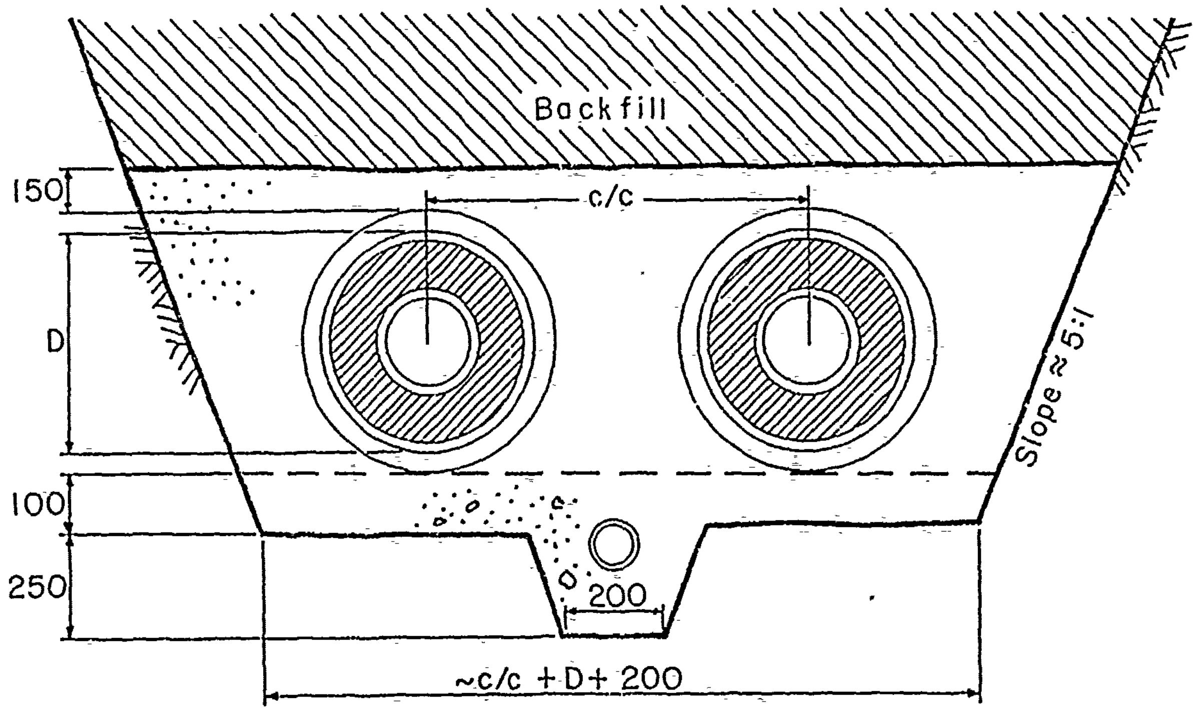
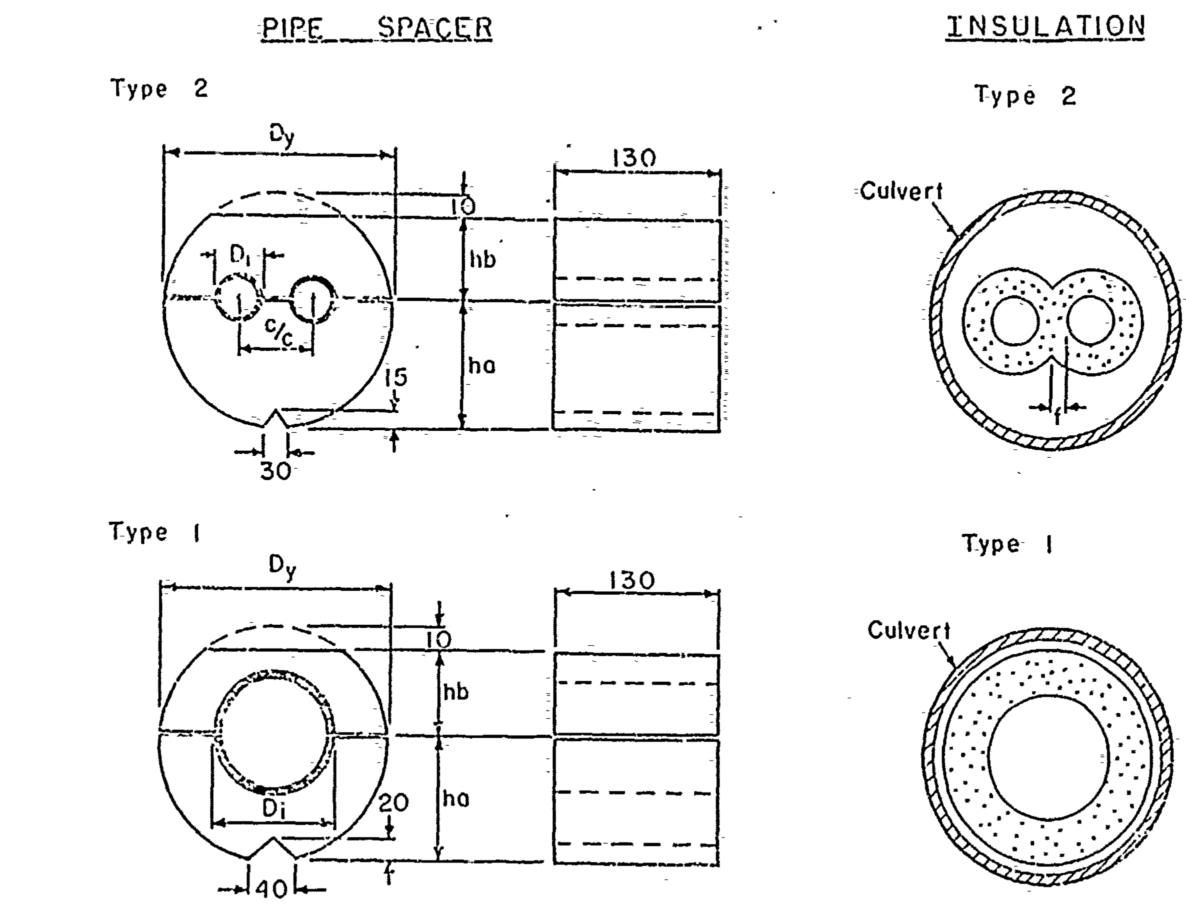
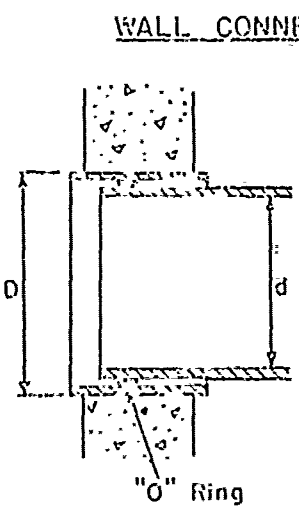


Figure 5.1.5 Typical Swedish hot water pipe installation in asbestos cement pipe, either singly or in pairs. (Also see Table 5.1.1)





Type			
Toschi		Italit	
d	D	d	D
200	245	200	268
250	299	250	322
300	353	300	378
350	409	350	439
400	463	400	497

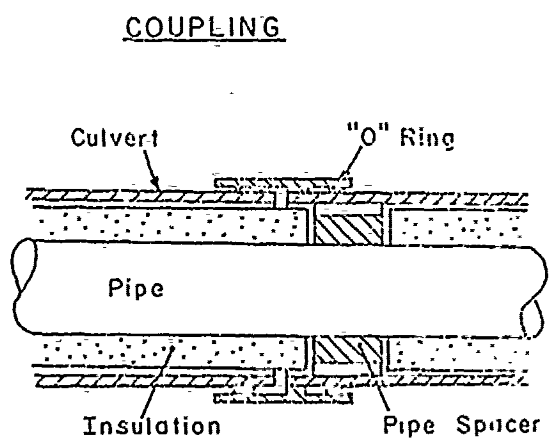


Figure 5.1.6.: Details of pipe spacers, wall connections and couplings for asbestos cement pipes.

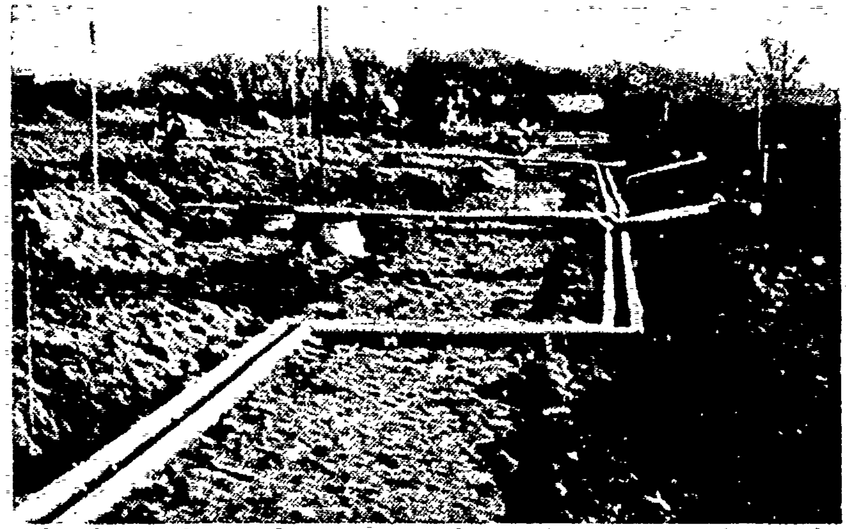


Figure 5.1.7: Directly buried insulated hot water pipes with plastic jacket during installation.

Figure 5.1.8: Close-up of plastic jacket pipe connections with heat-shrink joint seals.

Figure 5.1.9: Installation of directly buried flexible insulated pipe. This "cable-pipe" is produced in long continuous lengths and delivered on cable drums.

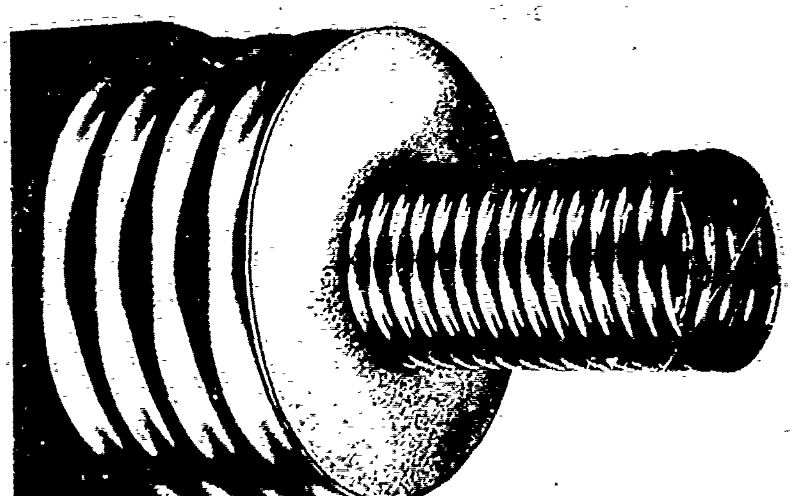


Figure 5.1.10.: Flexwell district heating pipe.

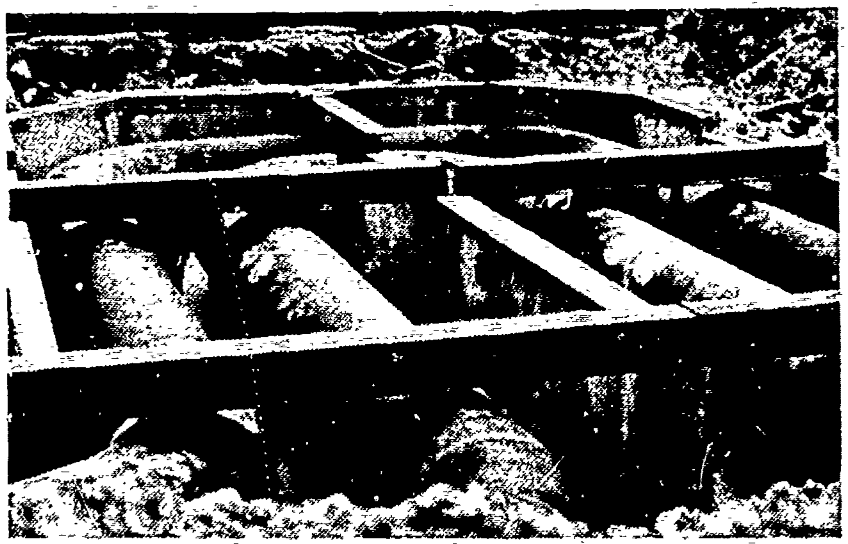


Figure 5.1.11: Expansion loops for 800-mm pipes in a concrete duct.

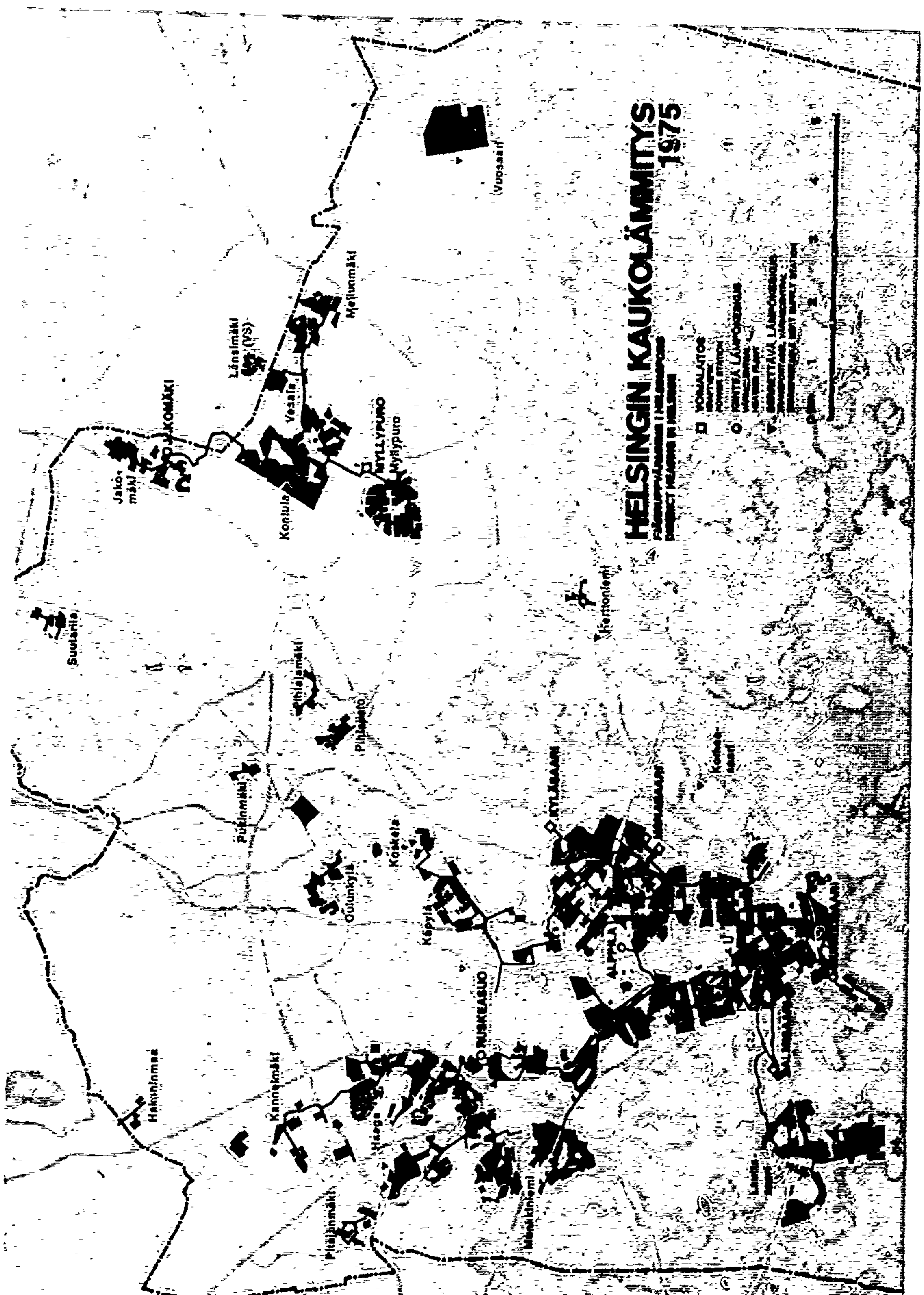
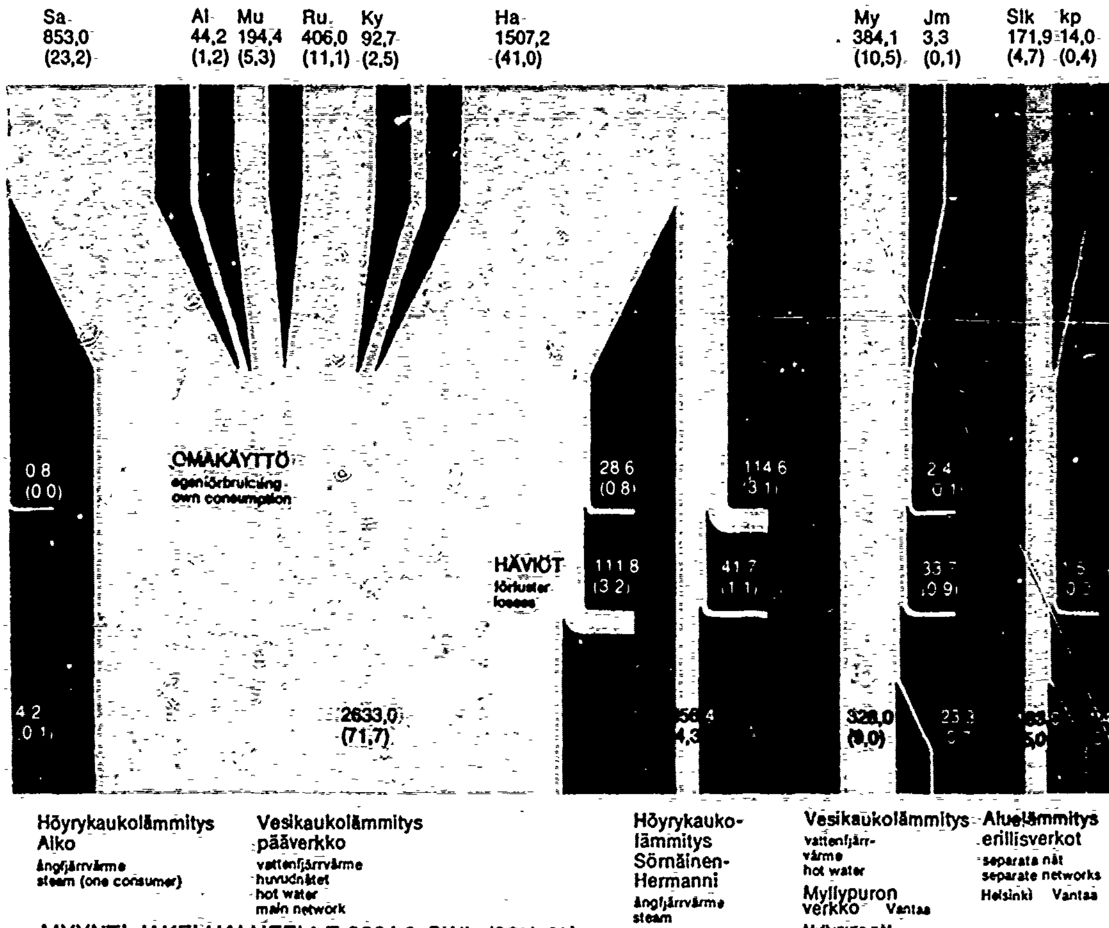


Figure 5.2.1.: District heating network of Helsinki, Finland.

LÄMMÖN HANKINNAN JA MYYNNIN JAKAUTUMINEN
FÖRDELNINGEN AV VÄRMEANSKAFFNING OCH FÖRSÄLJNING
DIVISION OF HEAT SUPPLY AND SALES

KOKONAISHANKINTA 3 670,8 GWh (100 %)
total anskaffning
total supplied



MYYNTI JAKELUALUEELLE 3304,6 GWh (90,1 %)
försäljning till distributionsområdet
sales to the distribution area

TOIMITUS JAKELUALUEEN ULKOPUOLELLE 24,7 GWh (0,7 %)
leverans utanför distributionsområdet
sales outside the distribution area

Sa	– Salmisaari	kraftvärmeverk, power and heat supply station
Al	– Alppila	toppvärmecentral, heating plant
Mu	– Munkkisaari	toppvärmecentral, heating plant,
Ru	– Ruskeasuo	toppvärmecentral, heating plant
Ky	– Kyläsaari	sopförbränningsanläggning, refuce incineration plant
Ha	– Hanasaari	kraftvärmeverk, power and heat supply station
My	– Myllypuro	kraftvärmeverk, power and heat supply station
Jm	– Jakomäki	toppvärmecentral, heating plant
slk	– siirrettävät lämpökeskukset	transportabla värmecentraler, transportable heat supply stations
kp	– Keskuspesula	centraltvätteriet, centrallaundry

Figure 5.2.2.: Energy balance for the district heating system in Helsinki, Finland.

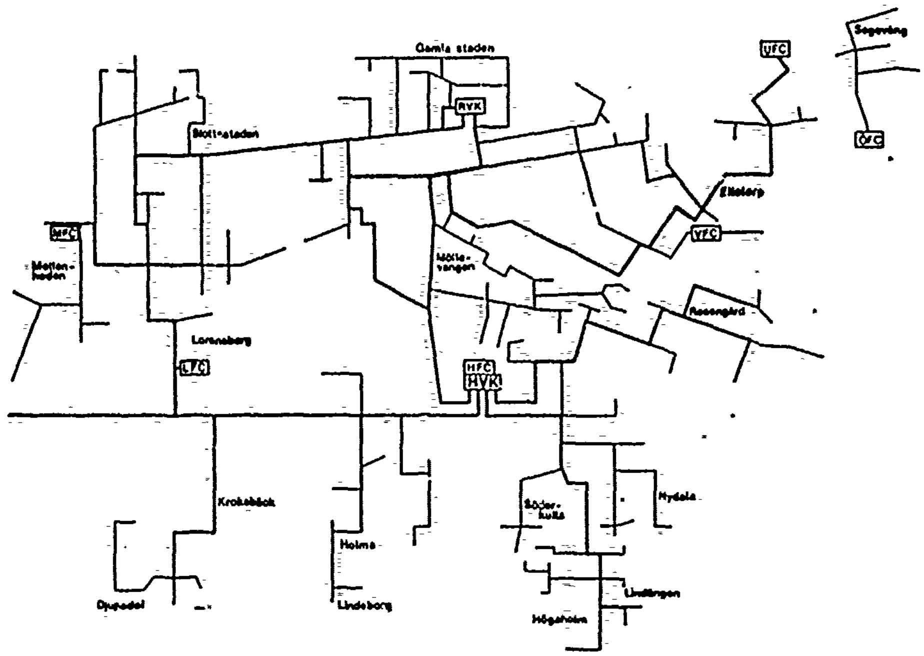


Figure 5.2.3.: District heating network of Malmoe , Sweden, showing the large heat and power plants (HVK, RVK), and the central heating plants (HFC, VFC, OFC, MFC, LFC, UFC).

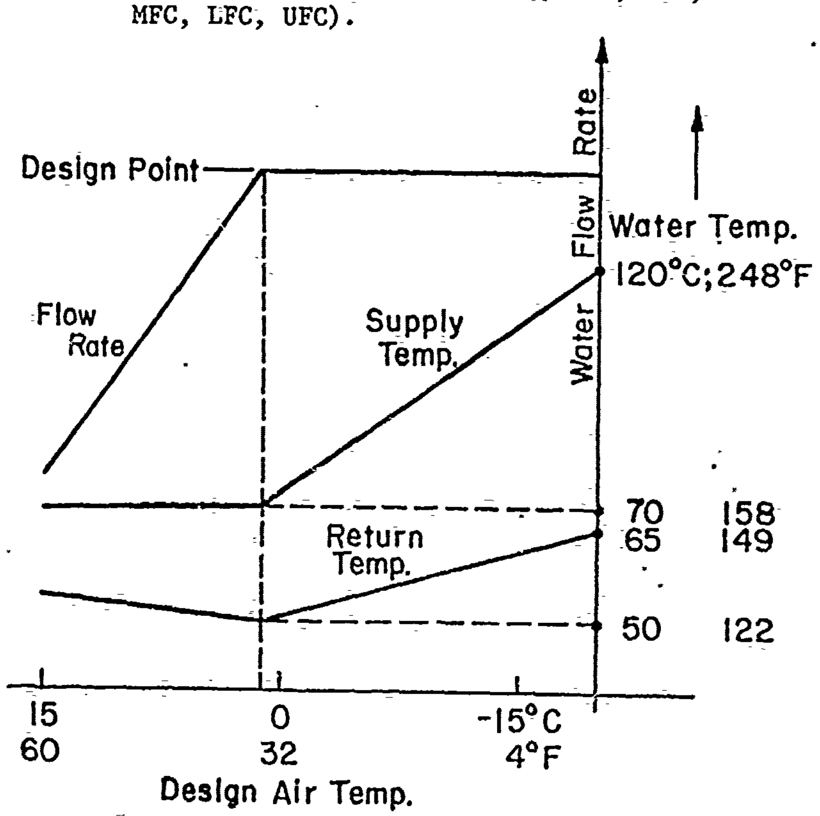


Figure 5.2.4.: Typical heat distribution water temperatures and flow rates. During cold weather the supply temperature is adjusted according to the air temperature while the flow rate is nearly constant at the design capacity.

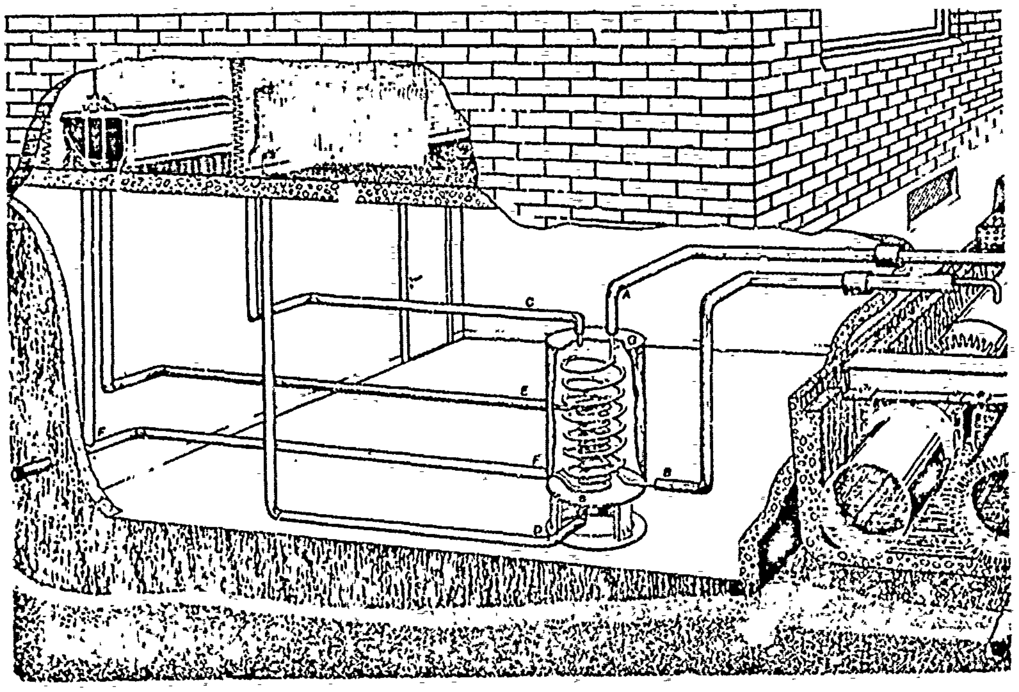


Figure 5.2.5.: Artist's sketch of a district heating system connection to a building. The heat exchanger is shown without valves and control equipment for clarity and to emphasize its simplicit, and compactness.

A = District heating water
Outgoing flow pipeline 120°C
B = District heating water
Return flow pipeline 70°C
C = Radiator system 80°C
D = Radiator system 60°C
E = Domestic hot water max 65°C
F = Tap water 5°C
G = Schematic heat exchanger

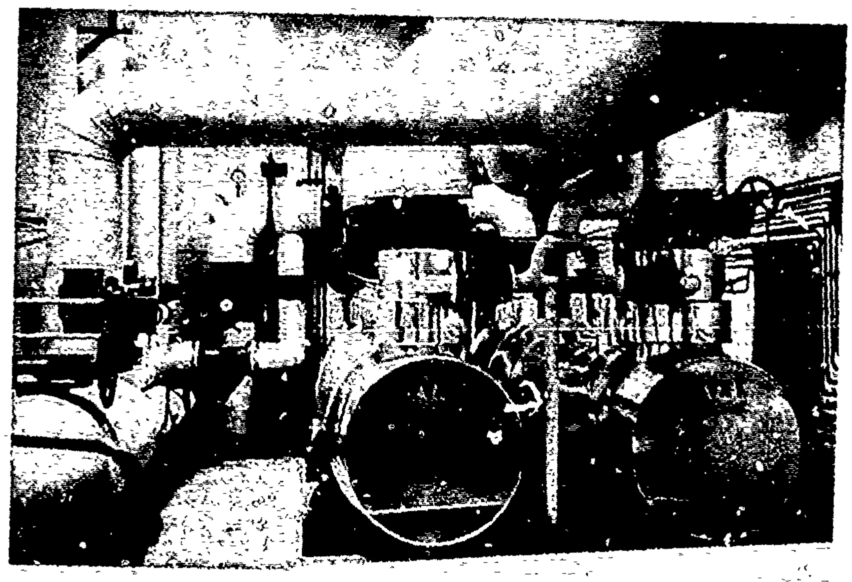


Figure 5.2.6.: Consumer substation for an apartment complex with about 2000 apartments in the Lorensborg area of Malmoe, Sweden.

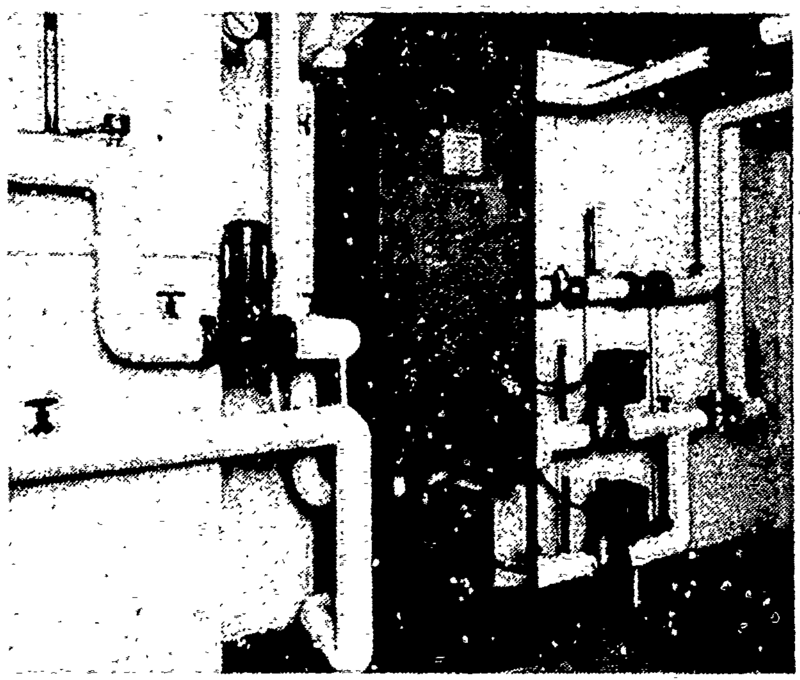


Figure 5.2.7.: Consumer service unit for a private house, containing the heat exchanger and controls in a package unit.

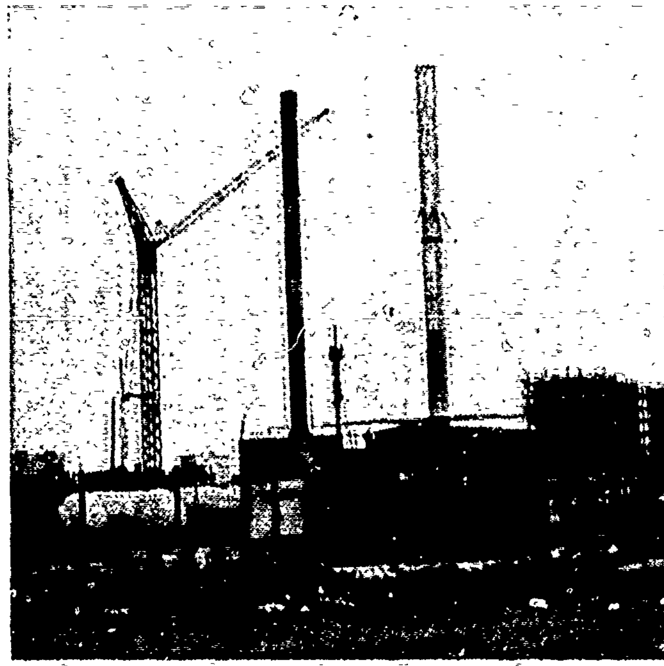


Figure 5.2.8.: Mobile heating plants in Malmoe, Sweden. The typical size is 3 MW (th) which can serve about 400 apartments.

Appendix 5.1.1.:

Planning and Construction of District Heating Pipelines

presented at
First International District Heating Convention
London, 1970

By
Mr. Risto Vartia
Helsingin kaupungin sähkölaitos

THIS report will concentrate solely on hot water district heating pipelines and on those pipeline constructions mainly used or in use in the district heating pipelines of the city of Helsinki (maximum pressure 11 at, maximum temperature 120°C).

General planning

The basis for the planning of pipelines must be a general plan of the distribution system with the areas to be heated, a determination of the heat demand, preliminary dimensioning of the pipelines and pressure losses.

PLANNING OF PIPELINES

The aim is to plan an optimum heat distribution system on the basis of the general plan in which both construction and maintenance costs have been taken into consideration. In order to achieve this result about half the planning must be based on information on operational experience and maintenance costs.

Planning of pipelines should at least include the following:

- collecting information on sites and conditions of possible routes, other pipelines, cables etc. along the routes,
- selection and levelling of routes,
- checking of transmission capacities,
- determination of sectioning points,
- estimation of sites, selection of types and construction of pipeline and determination of need for external drainage,
- final plan with route and profile drawings, including air release and emptying of pipes, anchoring and expansion compensation of pipes and drainage of duct,
- final estimate of the costs of the detailed plan mentioned above.

The collecting of preliminary information is most important in planning, as this avoids wrong selections of routes and type and construction of pipelines, as well as unpleasant surprises in carrying out the work. The crossing of district heating pipelines and other pipelines and cables in the city centre often makes work very difficult and expensive because electrical, telephone cables and gas pipelines are usually on the same street level as district heating pipelines.

In estimating sites, phreatic high, overflow limits, height of sea water, soil, traffic demands and other factors influencing selection both of type and construction must be taken into consideration.

Estimation of the site must include investigation as to whether drainage is necessary or whether it brings any advantage. In addition it must always be remembered that external drainage can never replace the internal draining of ducts.

Stop valves in the heat distribution system are needed for two reasons:

- when a network fed by two or more stations is divided up in special operational situations; and
- when a network is divided up because of connection of new pipelines or maintenance work in order to reduce interruptions in distribution or the water amount to be released.

It is unsatisfactory and expensive to install stop valves in every branch of an underground pipeline just for safety. Investment and maintenance costs then rise considerably because of the additional equipment to be maintained.

The need for stop valves in connecting new pipelines is reduced by the fact that a branch pipeline can nowadays be connected to the main pipeline without interrupting distribution. This method is shown in Fig. 1.

In selecting the type of pipeline the possibility of using cheaper types of pipeline i.e. pipelines in buildings or the open air must first be considered. These are also the best possible solutions as regards corrosion. In the case of underground pipelines it should be remembered that no duct is 100 per cent water tight, so that the ducts must always be made with a sufficient descent in a certain direction and an inspection and drain point for leak water must be provided at the lowest points. In damp places the pipeline must be built as near the surface of the ground as possible, to reduce the risk of water getting into the duct.

TYPES OF PIPELINE

There are three different types of pipeline in the heat distribution system:

- underground pipelines;
- pipelines in buildings or tunnels;
- pipelines in the open air.

Approximately half the heat distribution system comprises pipelines in buildings, tunnels and the open air and the other half underground pipelines.

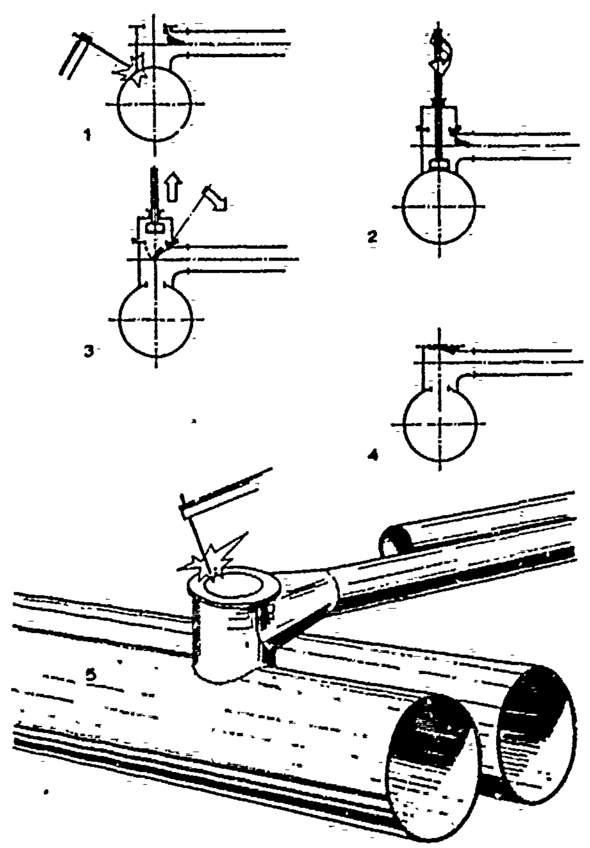


FIG. 1.—*Connection of a branch pipeline to the main pipeline without an interruption in the distribution*

1. A branch pipe equipped with a working opening is welded to the main pipeline.
2. A sawing device is fastened to the branch pipe and a hole is sawn to the main pipeline
3. The saw with the piece sawn from the main pipe is drawn to an upper position and the working opening is closed with a swing disk belonging to the branch pipe
4. The operating pressure in the pipe keeps the disk tight in the opening
5. The tightness of the branch pipe is strengthened through welding

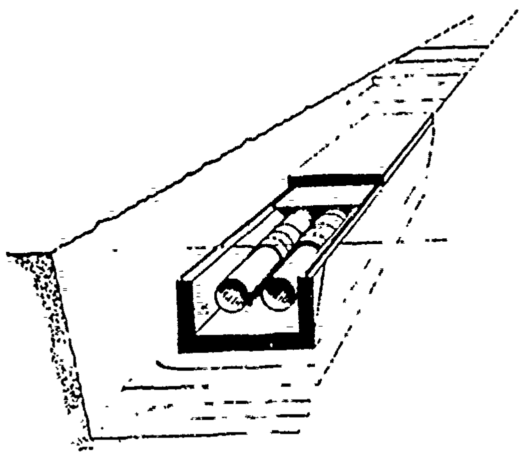


FIG. 2.—*Site-cast duct*

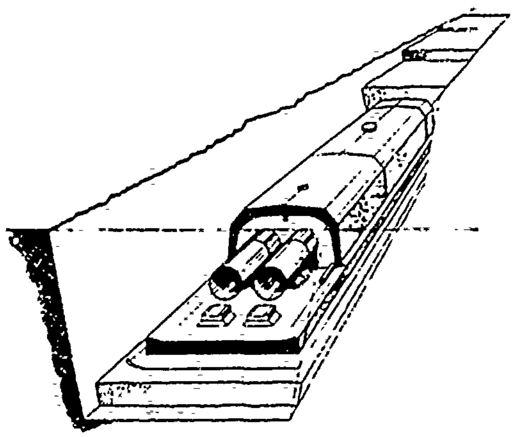


FIG. 3.—*Semi-prefabricated duct*

Underground pipelines

The cover solutions for underground pipelines can be divided into the following four groups:

- site-cast duct;
- semi-prefabricated duct;
- prefabricated duct;
- jacket construction.

The fact that there are several different cover solutions for underground pipelines naturally depends partly on local conditions, but certainly also on the fact that exchange of information on constructions, operational experience and costs has not been sufficient between different works, cities and countries.

In Helsinki the concrete constructions of ducts are generally dimensioned to endure without cracking a wheel load of 7000 kg + 40 per cent dynamic increase. In order to make the concrete constructions water-tight the breaking strength of the concrete must be at least 300 kp/cm^2.

Site-cast ducts

This duct construction is the least developed and most expensive, but when well done also the most water-tight solution. A prefabricated duct should be aimed at because this kind of construction reduces both working time and costs. On the other hand a site-cast duct is the best solution in exceptionally damp ground or in places where extreme strength is needed, e.g. in crossing railways. Fig. 2 shows this kind of duct. In very damp and muddy ground the duct must be water-pressure insulated and PVC-band must be used in joints between the wall and cover. The same kind of PVC tightening band is used in the shrinking joints at 25 m intervals in the duct.

The site-cast duct, the so-called rectangular duct and its different variations are the most general duct constructions in Europe.

Semi-prefabricated ducts

Construction is the first step towards prefabricated ducts and thus to reduced costs. It consists of a site-cast duct base and of a prefabricated cover, Fig. 3. The semi-prefabricated ducts vary in length according to size and type from 2 to 4 m. The joint of the base and cover is sealed either with cement mortar or with rubber bitumen band. The cross joints of prefabricated ducts are sealed with rubber bitumen band and protected with cement mortar. The shrinking joints of the duct base are made using PVC tightening band.

Prefabricated ducts

Figs. 4 and 5 show a prefabricated duct intended for pipe sizes 150 . . . 700 mm. The lengths of the prefabricated ducts vary according to size from 2 to 4 m. The lower parts of the ducts are welded together at four points. The cross and longitudinal joints of prefabricated ducts are made with rubber bitumen band. The cross joints are protected with cement mortar.

Fig. 6 shows a combination of a site-cast duct and of a prefabricated duct. It is used in a damper soil than the prefabricated duct. Nowadays it is also used in street crossings instead of site-cast ducts. The advantage of this

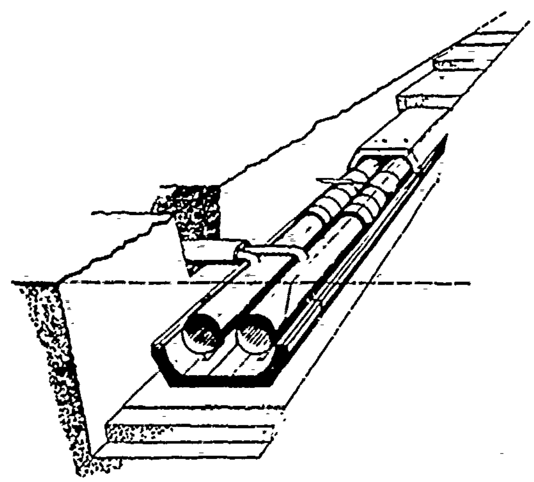


FIG. 4.—*Prefabricated duct*

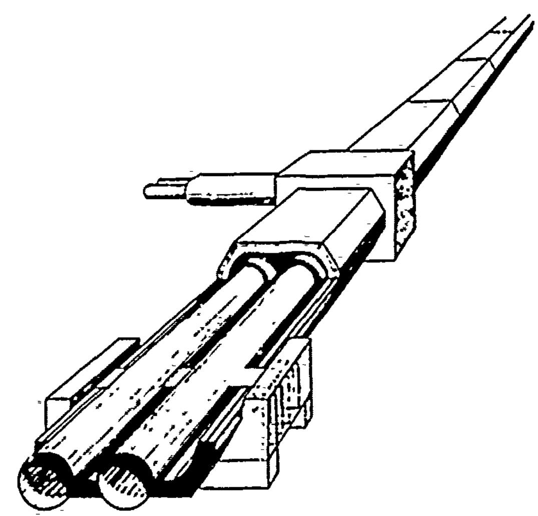


FIG. 5.—*Prefabricated duct: anchor point in the foreground*

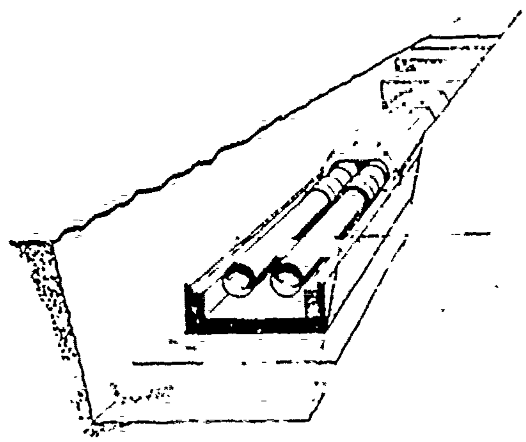


Fig. 6.—*Site-cast duct with prefabricated upper parts*

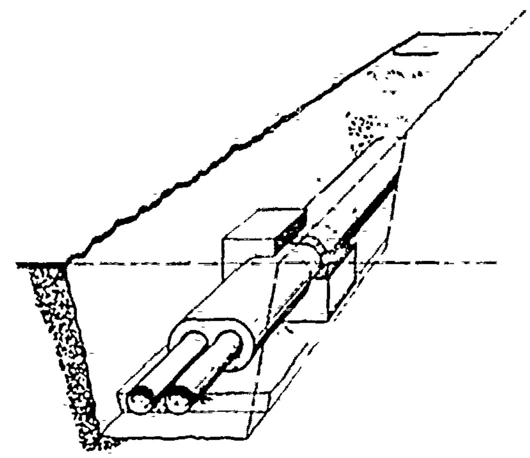


Fig. 7.—*Jacket pipeline*

solution is that after laying the prefabricated upper duct parts the ditch can immediately be filled and traffic is not disrupted.

The building costs of various cover solutions differ greatly. A site-cast duct for pipe size 600 mm costs about 1350 Fmk/m and the corresponding prefabricated duct only about half that. Part of the cost difference naturally depends on the fact that in Helsinki site-cast ducts are used in the worst conditions and at street crossings.

Jackets

Only one variation of this solution is nowadays used in Helsinki. This can be seen in Fig. 7. The space between the outer polyethylene shell and the inner glass fibre pipes is filled with hard polyurethane foam. Steel pipes are fitted inside the inner pipes. The prefabricated jackets are about 10 m long and they are jointed with rubber bitumen felt. The joint is protected with reinforced concrete or with shrink sleeves of polyethylene. Up to pipe size 125 mm both steel pipes ar inside the same jacket, but for bigger sizes two separate prefabricated jackets are used.

The advantages o this system are the small space requirement and relative gross length. It has proved satisfactory in branch pipelines between the main pipeline and buildings in the centre of Helsinki.

PIPELINE CONSTRUCTION

Pipes, elbows, Flanges

Appendices 1 and 2 are the recommendations made by the Study Committee on Pipelines of Lampolaitosyhdistys r.y. (Association of Finnish District Heating Undertakings) on the technical demands of pipes, elbows and flanges in district heating pipelines. Dimensions, material, conditions of supply, surface treatments, etc. are given.

Alignment guides, anchors and pipe supports

The constructions of pipe supports, alignment guides and anchors of underground pipelines can be seen in the enclosed figures. These constructions, with a semi-prefabricated duct insulated with aerated concrete, can be seen in Fig 8, those of the site-cast duct in Fig. 9 and those of the prefabricated duct in Fig. 10. The basis for planning of alignment guides and anchors of the prefabricated duct has been that the prefabricated upper duct parts can be laid as such over these constructions.

It is a general rule in the planning of support and alignment constructions that the pipe itself should never be the sliding surface.

The distances between pipe supports are as follows:
Figs. 8a, 9a, 10a

pipe size		700 ... 300 mm	6·0 m
,,	,,	250 ... 200 ,,	5·0 ,,
,,	,,	150 ... 65 ,,	4·0 ,,

The recommended distances between alignment guides are:
Figs. 8b, 9b, 10b

pipe size	1. distance from expansion joint	following distances
700 ... 500 mm	8 m	26 m
400 ... 350 ,,	6 ,,	20 ,,
300 ... 200 ,,	4 ,,	16 ,,
150 ... 80 ,,	3 ,,	10 ,,

The alignment guides used immediately on both sides of the axial expansion joints are shown in Figs. 8c, 9c and 10c. In prefabricated ducts, Fig. 10c, both pipes are put together by means of sliding guides between the pipes. Thus a weight is reached sufficient to resist the upward pushing component caused by any errors in laying the pipes.

Figs. 8d, 9d and 10d show anchors. The construction, Fig. 9d, with an upper balk and interlocking parts is used as an anchor in site-cast ducts. Earlier this kind of anchor was always made with two traverses, but in almost every case, depending on installation difficulties, one traverse alone took the whole force bearing on the anchor. The anchor of the prefabricated duct is of very light construction, e g. the whole anchor for pipe size 500 mm weighs only about 140 kg whereas the anchor with two traverses weighed about 580 kg. It must, however, be admitted that the omission of over-safety and the approval of a bigger permissible tensile strength have also influenced the weight reduction.

Thermal expansion and expansion joints

The thermal expansion of pipes is about 0·012 mm/m°C e.g. the change in length corresponding to a 120°C temperature difference is about 1.4 mm/m. In order to meet this expansion the following means and equipment are used.

- Natural bends alone are usually enough in pipelines in buildings, the open air and small underground pipelines. There must be then sufficient space for the pipes to move in the bend. If the movement of the pipe in the bend is δ and the pipes are 50 per cent prestretched the necessary pipe arm x for compensation can be determined by the formula $x = 63\sqrt{D \cdot 0\cdots\delta}$ where D is the outer diameter. Natural compensation must always be put to advantage whenever the route permits. It is a very reliable and cheap way to compensate thermal movements. On the other hand it is too expensive to make bends in underground mains only for natural compensation.
- Axial expansion joints are used to compensate mains, pipe size 200 ... 600 mm. These expansion joints normally have welding ends and are laid in the ordinary duct without inspection manholes or indications on the walls of buildings. It is too expensive and not advisable to build chambers for expansion joints. The bellows of the axial expansion joint are usually made of stainless

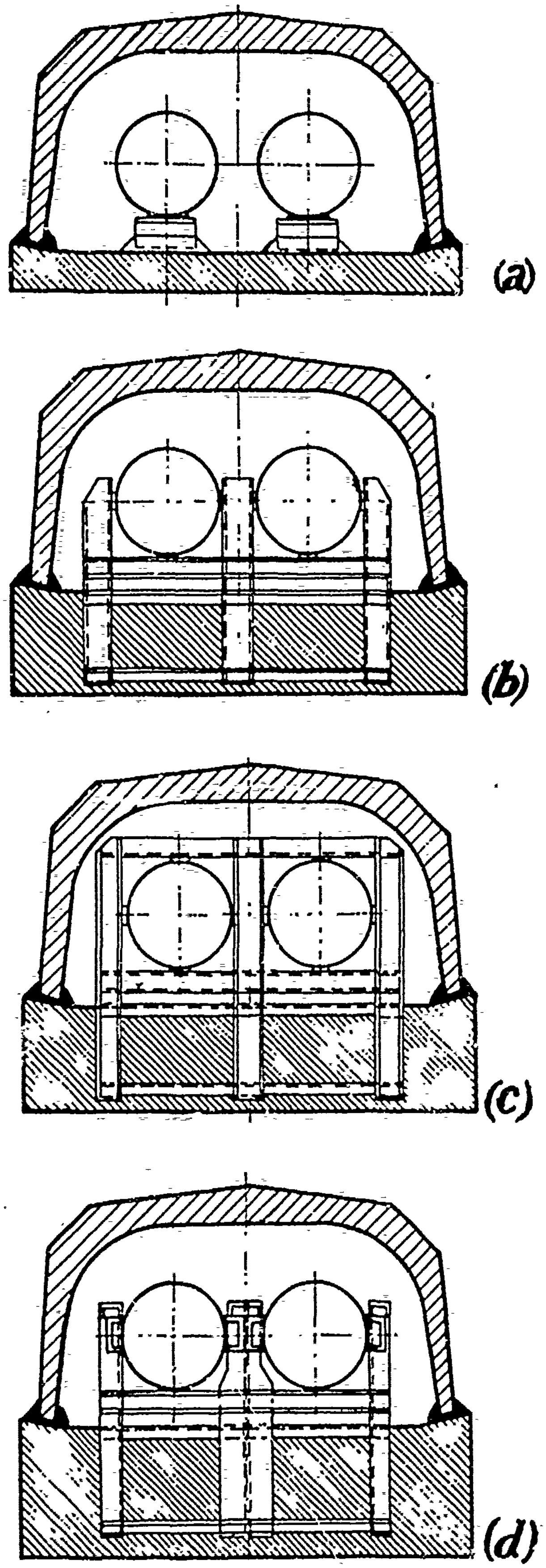


FIG. 8.—*Semi-prefabricated duct*

(a) Pipe supports
(b) Horizontal alignment guides
(c) Both horizontal and vertical alignment guides
(d) Anchor point

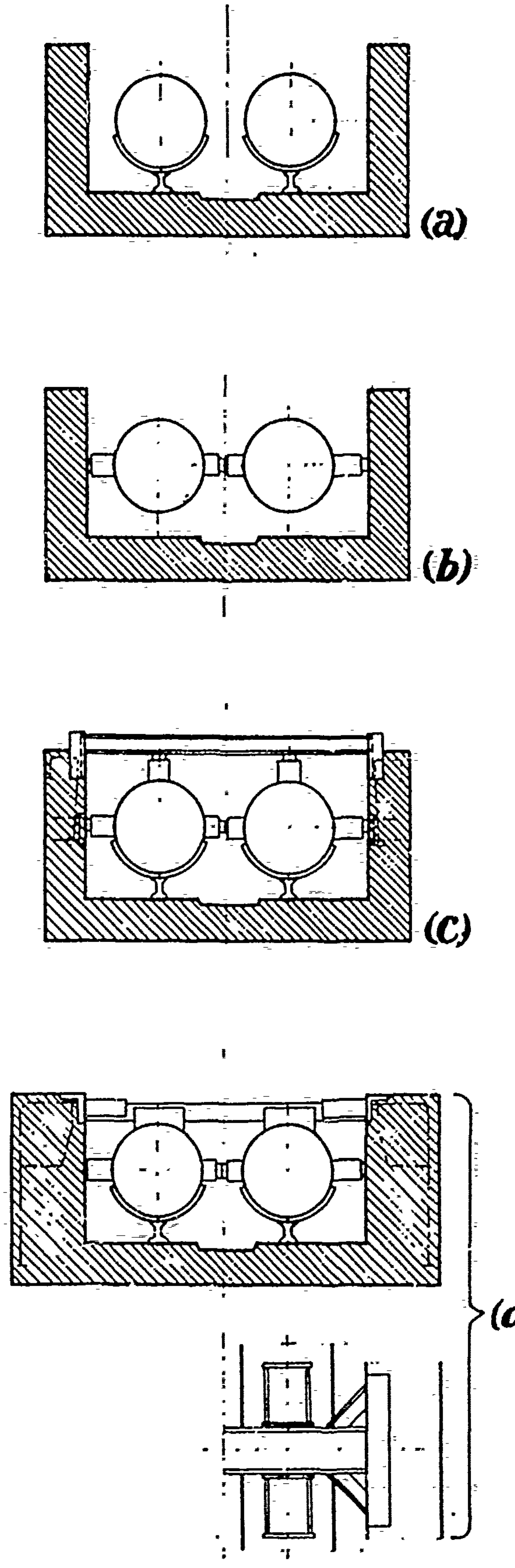


FIG. 9.—*Site-cast duct*

(a) Pipe supports
(b) Horizontal alignment guides
(c) Both horizontal and vertical alignment guides
(d) Anchor point

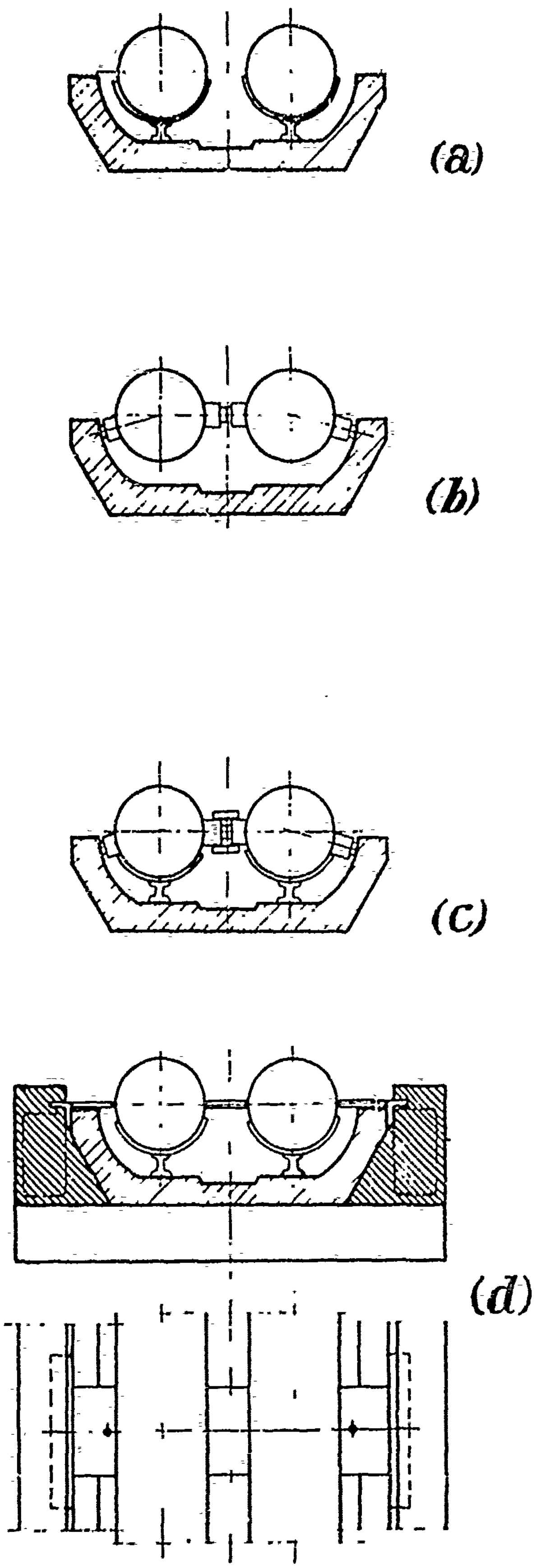


FIG. 10.—*Prefabricated duct*

(a) Pipe supports
(b) Horizontal alignment guides
(c) Both horizontal and vertical alignment guides
(d) Anchor point

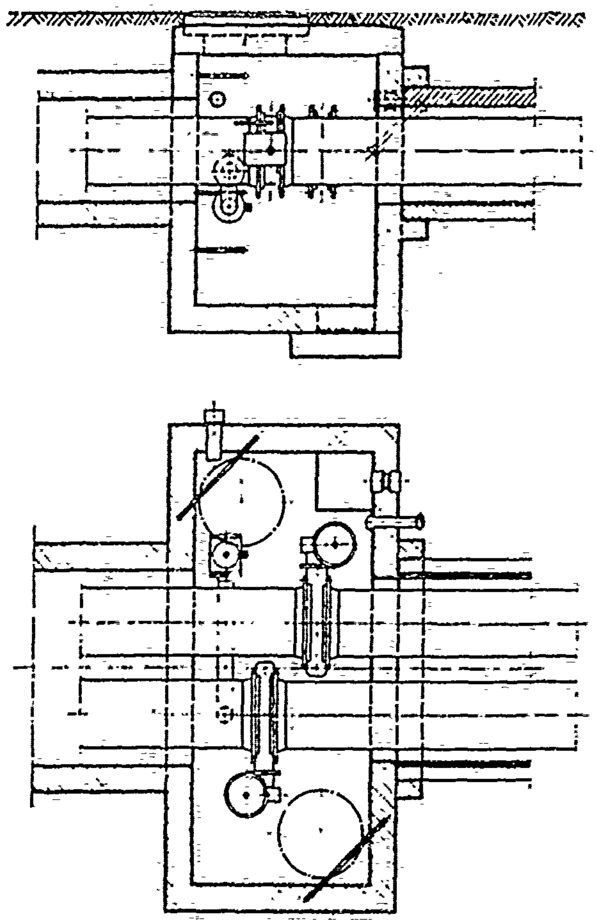


FIG. 11.—*Chamber with sectioning valves*

(18/8) steel. In soil where sea water or other salt water may enter the duct the use of expansion joints made of acid-resisting material must seriously be considered.

- Lateral expansion joints allow a bit compensation capacity and can thus be used in long straight mains without branch pipelines. When this type of expansion joint is used the anchor forces are very small.

Sectioning
A typical sectioning point of underground pipelines can be seen in Fig. 11. Butterfly valves have lately been used instead of lubricated plug valves as sectioning valves for the biggest pipe sizes. Lubricated plug valves are still used as stop valves for 200 mm or smaller pipes. Valves with flanges or valves pressed between flanges are used almost exclusively in Finland.

Vents and drains of the line
Facilities for air release must be arranged at the highest points and facilities for emptying at the lowest points of underground pipelines. A venting chamber can be seen in Fig. 12 and an emptying chamber in Fig. 13. If the water amount to be drained is small no drain is necessary and if the air amount to be released is small it is not worth building vents because there is always a risk of corrosion with manholes. On the other hand small air amounts do not cause much harm as the air dissolves in circulating water, whose hydrazine content eliminates the oxygen.
In Helsinki the emptying pipes for pipe sizes 200 . . . 300 mm are of pipe size 50 mm and those for 350 . . . 600 mm are 80 mm.

Heat insulation
Earlier aerated concrete was almost the only heat insulation material for pipelines. Its thermal conductivity is not very good, only about 0·08 W/m² °C. The aerated concrete insulation was cast on the spot through holes in the prefabricated ducts. The pipes could not be heated during

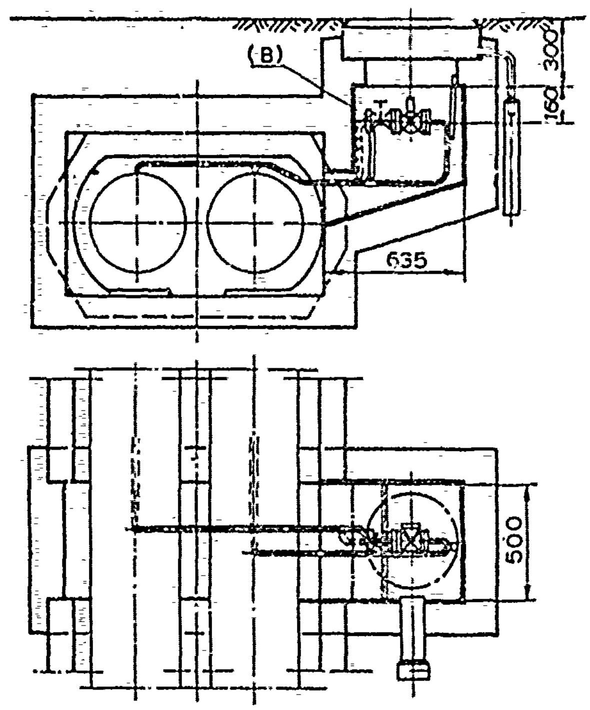


FIG. 12.—*Venting chamber*

insulation. In dry state this material has a density of 300 ± 25 kg/m³ and a compressive strength of 3 kp/cm². Nowadays formed mats of mineral wool are used as heat insulation in duct pipelines. The thermal conductivity of mineral wool is 0·04 W/m² °C. Thus the dimensions of the ducts are smaller and the building costs are reduced.

The thicknesses of mineral wool insulations in underground pipelines at present used in Helsinki are as follows:

pipe size	insulation thickness outgoing pipe	return pipe
700 . . . 500 mm	60 mm	40 mm
400 . . . 300 „	50 „	30 „
250 . . . 150 „	40 „	30 „

The insulation thicknesses naturally depend on the price of heat and on the construction costs of the pipeline. Calculations of optimum insulation thicknesses in Helsinki have shown that the insulation could have been omitted in the return pipe. Other factors, such as traffic inconvenience due to melting snow and the condensation phenomenon in inner surfaces of the duct call for insulation of the return pipe.

Polyurethane foam used in jackets provides even better insulation. Its thermal conductivity is about 0·02 W/m² °C, and it is relatively water and gas proof.

In Helsinki pipelines in buildings are insulated as follows:
- Formed mat of mineral wool;
- 1 layer of heavy building paper firmly glued at the seams;
- 1 layer of canvas firmly glued at the seams; and
- 1 coat of washable paint.

The insulation thicknesses used in pipelines in buildings are in Helsinki as follows:

pipe size mm	25	40	50	65	80	100	125	150 . . . 250
insulation thickness mm	20	30	30	40	40	50	60	60

Duct draining

It has been stated earlier that the duct must be built with a sufficient descent in a certain direction and an inspection and pumping point for leak water must be provided at the lowest point. The drainage point of a duct can be seen in Fig. 14.

Ducts insulated with aerated concrete should have holes for internal drainage so that any water can run to the pumping points. The drains are made of straw ropes or by drawing a steel ball through the insulation, but the results are not always satisfactory.

In ducts with mineral wool insulation the leak water can flow almost freely in water channels on the duct base.

In jacket pipelines leak water can flow inside the glass fibre pipes.

The drainage points must be inspected at regular intervals. If a lot of water continuously gets into the chamber this must be furnished with an automatic emptying pump and connected to the sewers.

Ventilation of ducts

The principle and installation of duct ventilation can be seen in Fig. 15. The principle is that ventilation pipes must be installed at the lowest and highest points of every duct. In a duct insulated with mineral wool ventilation is quite effective, but in ducts insulated with aerated concrete it is difficult to arrange. The ventilation holes in aerated concrete have been made by duct-tube or ball drawing method.

It is necessary to ventilate ducts in order to dry out insulations. The insulations in ducts should never be enveloped in air-proof materials.

CONSTRUCTION

Contractor system

District heating pipelines in Helsinki are built by private contractors. Most of the materials required are, however, bought direct by the Electricity Works, i.e. pipes, elbows, flanges, stop valves, expansion joints, prefabricated ducts, prefabricated jackets etc.

Form of contract

Unit prices are used for all jobs. One reason is that the need to quarry solid rock varies and information on other pipelines and cables in the streets is not accurate. Many changes must thus be made in plans while the work is in progress.

Scheduling the works

The schedule is divided up into eight phases as follows:
- street work, 1st phase: excavation, quarrying, levelling and covering the ground with macadam;
- installation of lower prefabricated duct parts;
- street work, 1st phase: concrete casting;

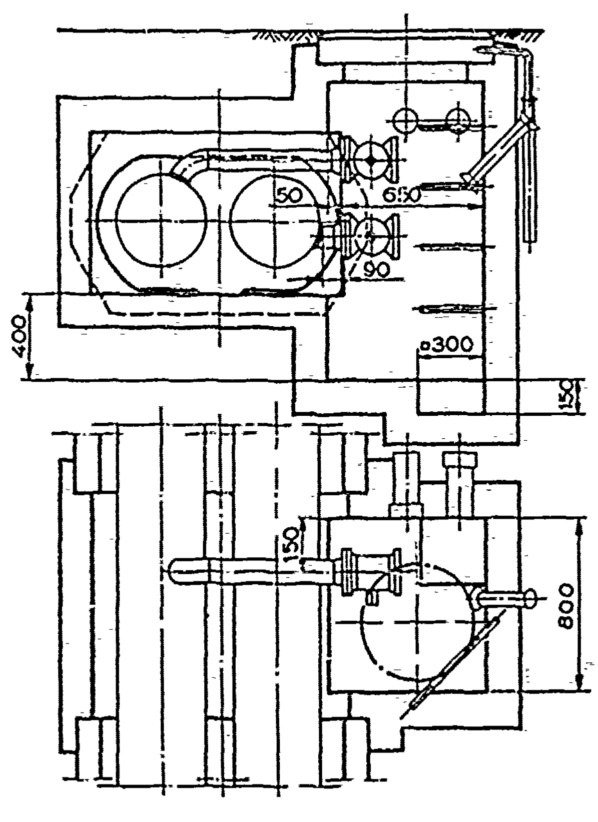


FIG. 13.—*Emptying chamber*

- pipe laying, including pressure test;
- insulation;
- installation of upper prefabricated duct parts;
- street work, 2nd phase: concrete casting and filling of the ditch;
- finishing, paving and asphalting.

The phases follow each other at intervals of one week, with the exception that there is an interval of 1·5 weeks between the street work, 1st phase, concrete casting and pipe laying, insulation follows pipe laying after 2·5 weeks (pressure test interval) and the installation of upper prefabricated duct parts follows half a week after insulation. The working speed of excavation and quarrying is critical and varies from 40 m/week to even 100 m/week, depending on pipe sizes, soil etc.

Work supervision

The supervision of building and laying prefabricated ducts must concentrate on quality control and especially on the joints of various duct constructions, the sealing of ducts and all points where working conditions are difficult. The surveillance of work done in winter must be very efficient. The control of building takes the form of random samples but it should always be so arranged that it can be changed on the basis of experience, working time and place in order to eliminate working errors as far as possible. Mass calculations in unit price contracts greatly increases the work of supervisors but in view of the importance of control for the working life of the pipelines it cannot be neglected.

Supervision of pipe work has always been careful enough in Helsinki. There are special welding tests for welders and their work is checked by taking X-ray photos. All welding seams must be in at least class 4 according to IIW (when class 5 is best). Finally a cold-water pressure test is made on pipes in which the pipes are hammered from seam to seam.

For the work to proceed the planner must participate in surveillance of the work. Information on changes in plans,

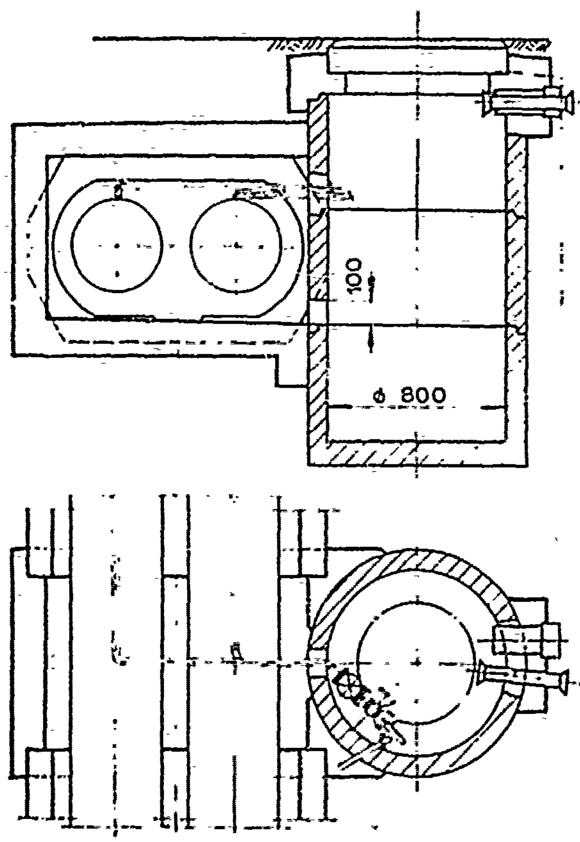


FIG. 14.—*Draining chamber*

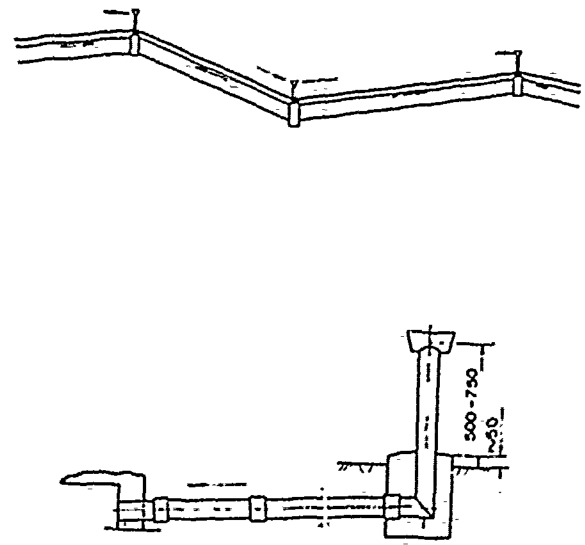


FIG. 15.—*Ventilation of ducts*

which often occurs in Helsinki, can thus reach the work site quickly.

Construction costs

The average construction costs for underground pipelines including sectioning points in the centre of Helsinki in 1968 can be seen in Fig. 16. The corresponding information on the suburbs is given in Fig. 17. General expenses also include removal of other lines and cables. The corresponding construction costs for pipelines in buildings can be seen in Fig. 18.

OPERATIONAL EXPERIENCE

A card has been filled in for every duct opening caused by construction work in Helsinki since 1966. This card gives information on the condition of pipes, insulations, drainage, ventilation etc. The cards already number about 120. On the basis of the material collected the condition of the networks can be considered good. Small working errors

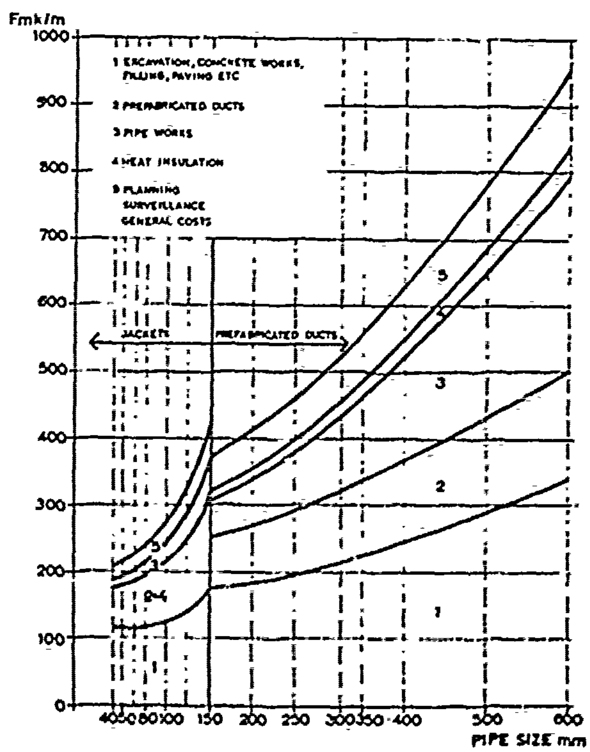


FIG. 16.—*Average construction costs of underground pipelines in Helsinki city centre in the year 1968*

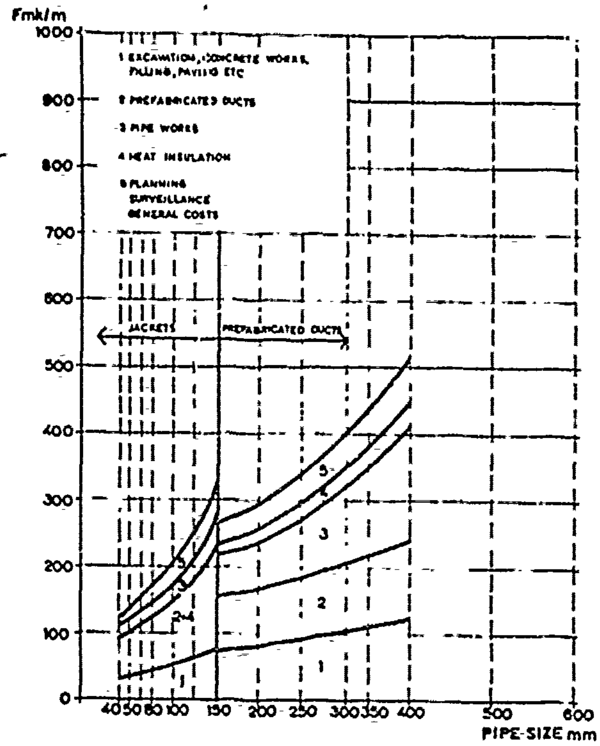


FIG. 17.—*Average construction costs of underground pipelines in eastern suburbs of Helsinki in the year 1968*

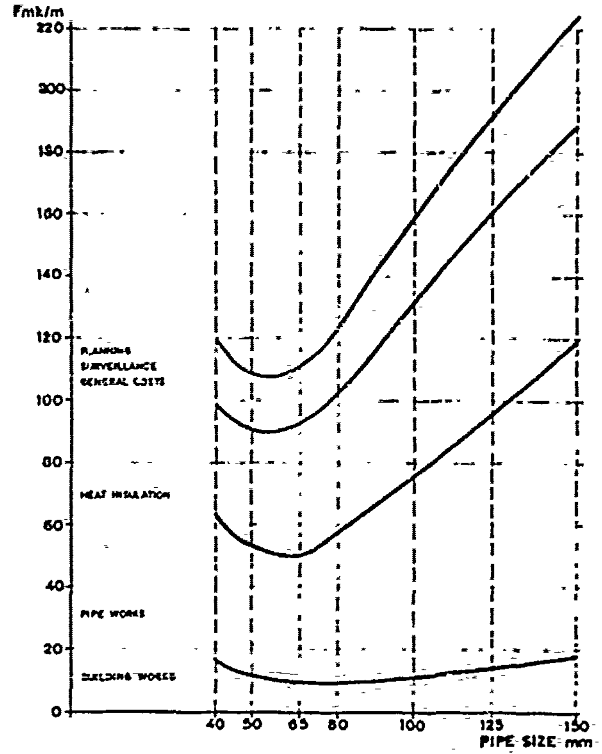


FIG. 18.—*Average construction costs of pipelines in buildings in Helsinki in the year 1968*

have been noted in about 10 cases, most of them in straw rope drains and duct joints.

Special attention must be paid to the control of building, because this work is most important for corrosion. On the other hand, solutions and constructions in which the surveillance of work or working results is difficult or even impossible should be omitted in planning. Finally, special attention should be called to the fact that the working life of pipelines also depends essentially on maintenance.

APPENDIX I

TECHICAL DEMANDS OF TUBES USED IN DISTRICT HEATING PIPELINES

1. Welded Steel Tubes

1.1. Dimensions: DIN 2458

nominal pipesize	outer diameter mm	wall thickness mm
700	711·2	8·8
600	609·6	7·1
500	508·0	6·3
400	406·4	6·3
350	355·6	5·6
300	323·9	5·6
250	273·0	5·0
200	219·1	4·5
150	168·3	4·0

1.2. Material:
St 37-2, DIN 17100/66

1.3. Other technical terms of delivery:
DIN 1626/65, sheet 3

1.4. Receipt
DIN 50049/60, point 2

1.5. Welding seam:
—The seam can be either longitudinally or spirally welded
—In the event of spirally welded tubes the weld must be 100 per cent X-rayed
—The welding seams must meet at least the X-ray classification 4 according to IIW
—The external welding bead should not exceed 20 per cent of the wall thickness of tube

1.6. Length
10–14 m

1.7. Ends of tubes
Calibrated and bevelled according to DIN 2559/62, form 2

1.8. Straightness of tubes
Straightness tolerance 15 mm/10 m

1.9. Pressure test
Every tube must be hydraulically tested to at least 25 kp/cm² cold water at the factory

1.10. Surface treatment
Outer surface treatment of tubes must be done at the factory after fabrication with such rust preventer which protects the tubes in transit and during a short stocking at the customer

2. Seamless Steel Tubes

2.1. Dimensions
DIN 2448/61

nominal pipesize	outer diameter mm	wall thickness mm
150	168·3	4·5
125	139·7	4·0
100	114·3	3·6
80	88·9	3·2
65	76·1	2·9
50	60·3	2·9
40	48·3	2·6
32	42·4	2·6
25	33·7	2·6
20	26·9	2·3
15	21·3	3·2

2.2. Material
St 35

2.3. Other technical terms of delivery:
DIN 1629/61, sheet 3

2.4. Receipt:
DIN 50049/60, point 2

2.5. Length:
6–12 m

2.6. Ends of tubes:
—nominal pipesize mm 150: calibrated and bevelled according to DIN 2559/62 form 2
—nominal pipesize mm 125 . . . 15 straight, smooth

2.7. Pressure test:

Every tube must be hydraulically tested to at least 25 kp/cm² cold water at the factory

2.8. Surface treatment:

Outer surface treatment of tubes must be done at the factory after fabrication with such rust preventer which protects the tubes in transit and during a short stocking at the customer

SUPPLEMENTARY EXPLANATION TO TECHNICAL DEMANDS OF TUBES USED IN DISTRICT HEATING PIPELINES

1. Welded Steel Tubes

1.1. Dimensions:

As to nominal pipesizes 700 and 600 the committee suggests 8·8 and 7·1 mm wall thicknesses instead of 7·1 and 6·3 mm because in practice it has proved to be so that the first mentioned thicknesses do not guarantee the cross-section of tubes to be round in transit and in stock.

The dimensions of tubes correspond to the norm ISO R 64.

1.2. Material:

So far steel St 37-2 or St 34-2 fabricated by Siemens-Martin method has been selected by members to be tube material. The committee thinks that both steel qualities are almost equally good in district heating pipelines when welding and other characteristics have been taken into consideration. On the market there is as tube material also steel fabricated with modern special methods. These materials fit for use, too.

The most important thing in selecting tube material is that the steel meets the demands of the selected norm (DIN 17100/66) and not the fabrication method.

1.4. Receipt:

The supplier must present a certificate of the factory of the receipt of every lot according to the norm DIN 50049/2. The manufacturer pays the costs caused by the receipt.

1.5. Welding seam:

Longitudinally and spirally welded seams are equally good.

1.10 Surface treatment:

The examinations have proved that the thickness of protection film of usual rust preventers such as Inferrugol, Tectyl 506, Shell Ensis Fluid 260 etc. should be at least 0·05 . . . 0·10 mm.

2. Seamless Steel Tubes

General:

Seamless steel tubes can be replaced by high frequency welded steel tubes which as to material and other technical characteristics meet the above mentioned demands.

2.2. Material:

In pipelines placed in cellars, tunnels and other rooms inside buildings tube material can be of normal commercial quality (St 00).

2.5. Length:

Demands of length and length tolerances of tubes can essentially influence the price of tubes.

APPENDIX II.

TECHNICAL DEMANDS OF ELBOWS AND FLANGES USED IN DISTRICT HEATING PIPELINES

1. Steel Welding Elbows

1.1. Dimensions:

Dimensions corresponding to welded steel tubes (DIN 2458/61), nominal pipesizes 700 . . . 200.

nominal pipesize	outer diameter mm	wall thickness mm
700	711·2	8·8
600	609·6	7·1
500	508·0	6·3
400	406·4	6·3
350	355·6	5·6
300	323·9	5·6
250	273·0	5·0
200	219·1	4·5
150	168·3	4·5
125	139·7	4·0
100	114·3	3·7
80	88·9	3·2
65	76·1	2·9
50	60·3	2·9
40	48·3	2·6
32	42·4	2·6
25	33·7	2·6
20	26·9	2·3

The radius of curvature must be about 1·5 × inner diameter of the elbow.

The elbows are of 90 degrees.

1.2. Fabrication method and material:

A. Seamless elbows are made of material St 35

B. Longitudinally welded elbows made of pressed parts are of material 37-2 (DIN 17100/66)

The welding seams of welded elbows must meet at least the X-ray classification 4 according to IIW.

1.3. Technical terms of delivery:

DIN 1629/61, sheet 3

1.4. Receipt:

DIN 50049/60, point 2

1.5. Ends of elbows:

—nominal pipesizes 700 . . . 150: calibrated and bevelled according to DIN 2559/62 form 2

—nominal pipesizes 125 . . . 20: straight, smooth

1.6. Pressure test:

The elbows must be hydraulically tested to at least 25 kp/cm² cold water

1.7. Surface treatment:

Outer surface treatment of elbows must be done at the factory after fabrication with such rust preventer which protects the tubes in transit and during a short stocking at the customer.

2. Steel Welding Neck Flanges

2.1. Dimensions:

Nominal pressure 10 DIN 2632, nominal pressure 16 DIN 2633.

nominal pipesize	outer diameter of neck mm	wall thickness of neck mm
700	711·2	8·8
600	609·6	7·1
500	508·0	6·3
400	406·4	6·3
350	355·6	5·6
300	323·9	5·6
250	273·0	5·0
200	219·1	4·5
150	168·3	4·5
125	139·7	4·0
100	114·3	3·6
80	88·9	3·2
65	76·1	2·9
50	60·3	2·9
40	48·3	2·6
32	42·4	2·6
25	33·7	2·6
20	26·9	2·3
15	21·3	2·0

As to nominal pipesizes 700 . . . 200 the wall thicknesses depart from the norms DIN 2632 and DIN 2633.

2.2. Material:
St 37-2, DIN 17100/66

2.3. Receipt:
DIN 50049/60, point 2

2.4. Welding ends of flanges:
—nominal pipesize 700 . . . 150 DIN 2559/62, form 2
—nominal pipesize 125 . . . 15 DIN 2559/62, form 1

2.5. Drilling of flanges:
Bolt holes:
—nominal pressure 10 according to DIN 2632
—nominal pressure 16 according to DIN 2633

6. Surface treatment:
Outer surface treatment of flanges must be done at the factory after fabrication with such rust preventer which protects the tubes in transit and during a short stocking at the customer.

Revisions for 1974

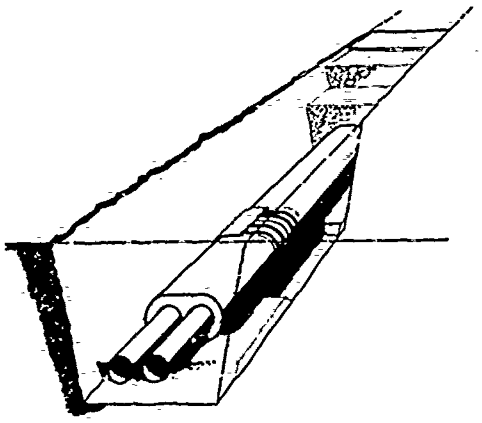


Figure 7 (revised)

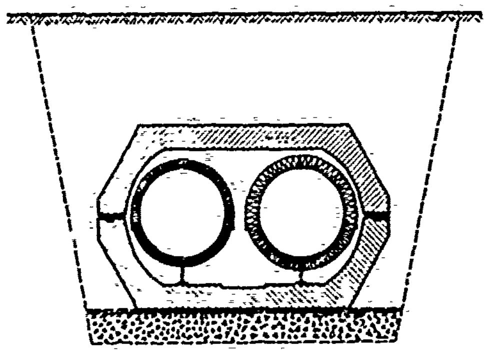


Figure 8 (revised)

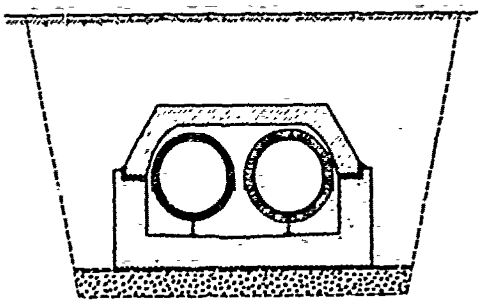


Figure 9 (revised)

Underground district heating construction in new areas of Helsinki, 1974.

1. Excavation, etc.
2. Prefabricated ducts
3. Steel pipes
4. Heat insulation
5. Planning, supervision, general costs

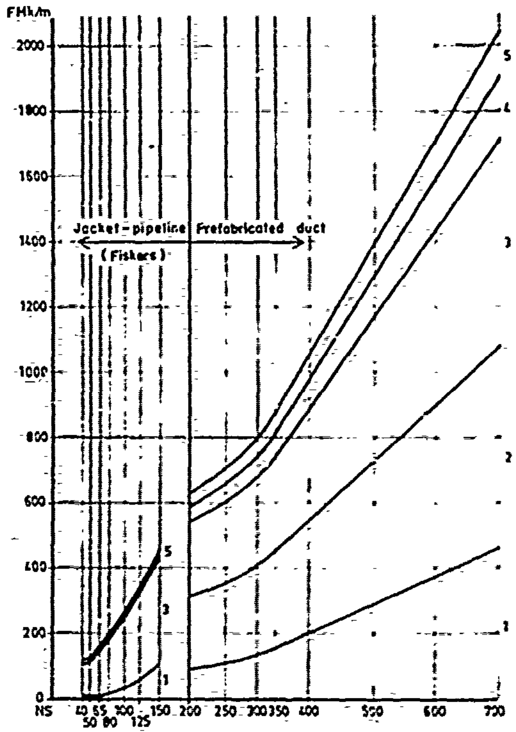


Figure 17 (revised)

Figure 3 (deleted)

Appendix 5.1.2.: FISKARS heat insulating culvert.

Fiskars insulating culvert is an excellent solution for insulating and supporting underground heat piping. It is suitable not only for district heating pipelines and hot-water pipes, but also for industry pipelines, such as oil pipes. These Fiskars elements can also be used for cooling pipes; in that case, however, the condensation must be considered.

Fiskars insulating culvert is a 'ready-made' duct construction. There is no need for concrete channels nor for separate pipe clamps, not even below streets. The culvert elements are simply fitted on, as the pipe welding proceeds. Then after a pressure test the shrink sleeves are pushed over the joints and shrunk on by heating. The culvert is covered with 0,5 m of soil, and the duct is ready.

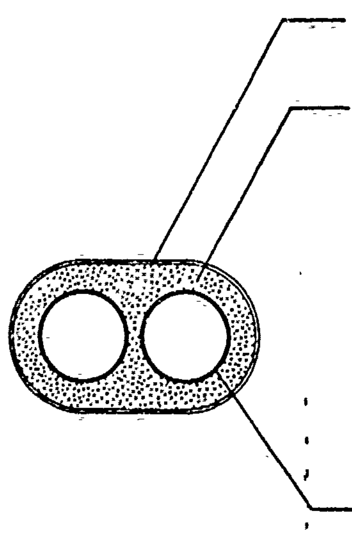
Fiskars culvert elements form a water-tight system, where the pipe can expand freely in the internal duct of the culvert. These internal ducts form a mechanical protection for the heat insulation and allow moisture to evaporate. Thus, the space around the pipes guarantees ventilation, keeps the pipes dry and prevents corroding.

Fiskars culvert elements are light and therefore easy to handle. The elements are easily cut, bends fitted, etc., as the culvert can be sawn with a normal hand saw.

Fiskars will be glad to furnish you with detailed instructions for installation including thorough descriptions of every phase of the work.

NOTE!	**Fiskars insulation culverts are always supplied without the steel pipes; in this respect they differ from most competitive systems.**

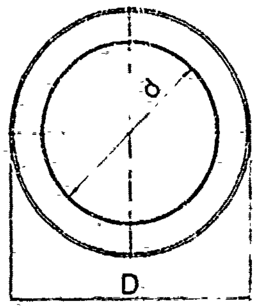
CONSTRUCTION



External covering: HD-polythene, black, thickness 2,5–5 mm depending on culvert dimensions.

Heat insulation: Hard polyurethan foam of special composition with a softening point of > 170°C, weight by volume ca 80 kg/m³, primary heat conducting figure $\lambda_{20°} = 0{,}018$ kcal/m · h · °C. In practice, however, it must be noted that as the foam grows older its λ-value at an average temperature in the insulating layer (i.e. about 55°C) = 0,026 kcal/m · h · °C. The heat insulation consists up to about 95 % of closed cells and does not, therefore, mechanically absorb water. Its hygroscopic moisture also is very low (about 3 weight-%, i.e. 0,2 volume-%).

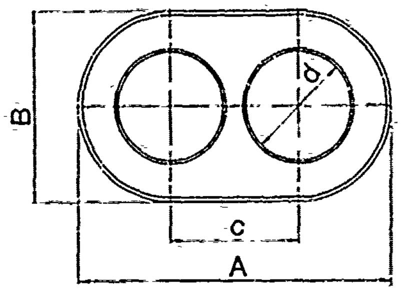
Pipe ducts: Glass fibre reinforced polyester plastic for high temperatures. Thickness 1,5–4 mm according to dimensions.



Single culvert

Size (No.) IS)	Pipe O.D. max.	Dimens. of culvert		
		d	D	Weight kg/m
1×150	168,3	183	280	9,2
1×200	219,1	254	355	13,2
[1] 1×250	273,0	303	410	14,8

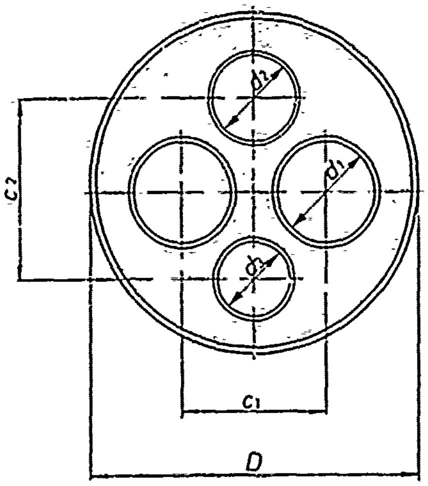
Standard length 10,5 m



Double culvert

Size (No.)	Pipe O.D. max.	Dimens. of culvert				
		d	c	A	B	Weight kg/m
2× 40	48,3	60	83	215	132	4,0
2× 50	60,3	70	100	247	147	4,8
2× 65	76,1	85	115	282	167	6,4
2× 80	88,9	103	130	317	187	8,1
2×100	114,3	131	160	390	230	12,0
2×125	139,7	155	195	450	255	14,6
2×150	168,3	183	227	515	288	17,5
[2] 2×200	219,1	239	284	629	345	23,4

Standard length 10,5 m

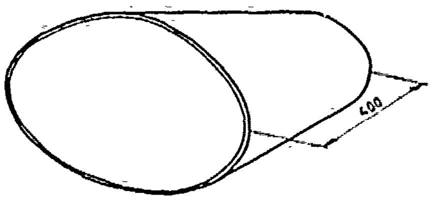


4-pipe culvert

Size (No.)	Pipe O.D. max.	Cu pipe max. d	Dimens. of culvert						
			d_1	d_2	d_3	c_1	c_2	D	Weight kg m
2× 50/40/32	60,3	47/33	70	60	48	107	125	240	6 9
2× 65/50/40	76,1	59/47	85	70	60	122	143	270	8.8
2× 80/65/50	88,9	76/59	103	85	70	157	181	332	12.6
[1] 2×100/65/50	114,3	76/59	131	85	70	167	223	379	16.4

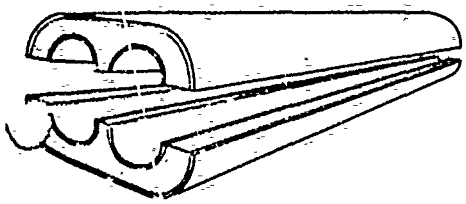
Standard length 10,5 m

[1]) Manufactured to order only.
[2]) Manufactured to order only, length 5,25 m



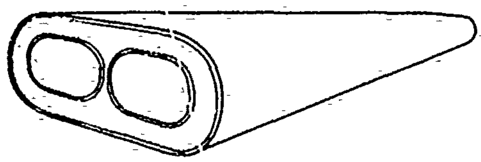
Shrink sleeves

For each culvert size there is a suitable shrink sleeve in such a size that it can be easily pushed over the culvert joint. It is shrunk on by heating and covered with a bitumen strap to give a tight joint.



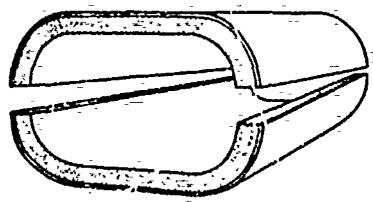
Culvert channels

All single and double culverts are also delivered in pieces of 2 m long halves (in pairs). These are used if the ends of the culverts at pipe joinings cannot be pushed together, or if for some reason an opening between the ends is desirable. The space is then filled with culvert channels cut into fitting lengths.



Conical culvert elements

Double culverts are also supplied as 5 m long conical elements. When mounted in 90° bends they allow for a 60 mm heat expansion in the steel pipes, whatever the end dimension in one end.

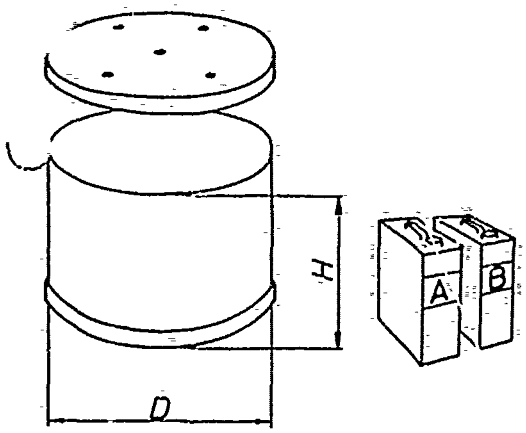


Special culvert channels

For all single and double culverts there are special channels with glass fibre surface for bellow compensators. They are 2 m long, their inner diameter being the same as the outer diameter of the standard culvert.

Hard foam wells

Hard foam wells can be foamed on the site and made into tight wells for bends and branches. They are delivered complete in four sizes.



Size	D	H
1	500	330
2	600	400
3	800	550
4	1000	750

Sealing straps

For shrink sleeves and wall lead-throughs there is a special dimensioned PIB-strap, 5×20 mm, delivered in rolls of 2×9 m.

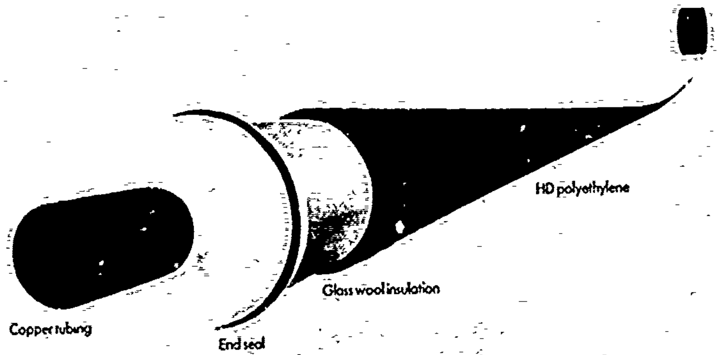
For sealing bends and anchor points we recommend a rubber-bitumen strap is rolls of 10 m, width 100 mm.

Appendix 5.1.3.: Aquawarm preinsulated district heating pipe (from manufacturer's brochure by Teplo International AB, Sweden).

Aquawarm copper district heating pipe.

Aquawarm is district heating piping made of copper. The tube is insulated with glass wool and the sheathing is made of HD polyethylene. The materials are corrosion-resistant and non-ageing throughout.

Corrosion-resistant district heating systems.



Copper is a noble metal. It has excellent corrosion resistance, and if a copper tube is to corrode at all, the water flowing in it must contain free oxygen. In a closed-circuit heat distribution system, the water is deaerated, and copper tube is therefore not exposed to any risk of corrosion.

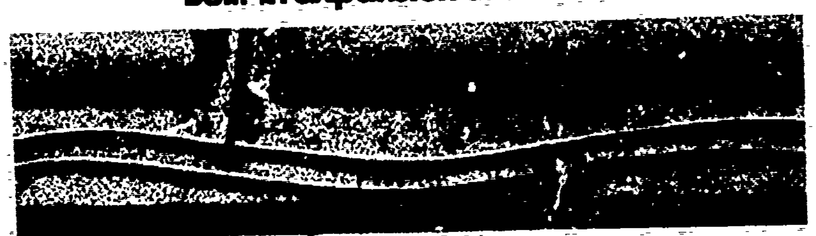
Flow velocities of up to 10 m/s (33 ft/s) are permissible without risk of damage to the tube. In the case of domestic hot water pipes carrying aerated water, the limits specified by the nomogram on page 11 should not be exceeded.

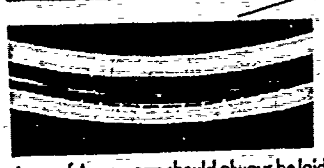
The glass wool insulation around the copper tubing can withstand temperatures of up to 400°C (750°F), and the material is non-ageing as well as water-repellent. The glass wool is compressed to a density which provides the best possible insulating characteristics at the relevant temperatures. (At 50°C, for instance, the coefficient of heat transmission is 0.03 W/m°C.)

The sheathing is made of HD polyethylene, of the same grade as that used for pressurised water pipes. HD polyethylene is a corrosion-resistant material which has an almost indefinite life in the ground.

The end seal prevents water from seeping through to adjacent pipe sections if the sheathing of one section should be punctured. And groundwater coming into contact with the copper tube is not particularly serious. Copper is not attacked by humic acids or chloride ions from the salt used for clearing snow off roadways.

Built-in expansion allowance.





A run of Aquawarm should always be laid in a roughly sinusoidal pattern. When the temperature of the copper tube increases, the tube will expand and the amplitude of the curve (height of arc) will increase. The insulation will be compressed at the outer radius, whereas the plastic sheathing will remain stationary in the ground. The actual amount of movement is very little, since it is uniformly distributed onto all of the arcs. At the usual temperature changes occurring in the primary distribution network of a district heating system, the movement is no more than about 5 mm.

6. Long distance heat transmission.

Discussions of long distance heat transmission and advanced planning concepts were discussed with personnel of the Studsvik Research Center in Sweden as well as with the Swedish district heating agencies listed in the preceding chapter.

As district heating systems grow, larger base load plants and bigger and longer main transmission lines are built. When nuclear heat and power plants are planned, their location is usually intended to be remote from urban centers and their district heating networks. Thus, long distance heat transmission becomes a major planning factor.

The connected heating load in Stockholm approaches 1000 MW(th) (3414 million BTU/hr), and is expected to reach 2000 MW(th) in the 1980's. The current load in greater Stockholm is near 1800 MW(th) and is growing faster in the surrounding communities. In Malmoe the connected heating load is also approaching 1000 MW(th) and is expected to reach 2000 MW(th) in 1990. A typical large nuclear plant produces about 3000 MW(th) which is converted into about 1000 MW electricity and 2000 MW waste heat. When operated as a heat and power plant, it produces about 700 MW electricity and 2300 MW district heat.

Heat transmission is feasible over greater distances as the amount of transmitted energy increases, just as with electrical transmission. Studies at the Studsvik Research Center in Sweden show that distances of 60 miles and greater are feasible for heat transmission of 1000 to 2000 MW(th) from a nuclear plant, compared with the cost of district heat from local oil-fired heating plants.

6.1 Large pipe systems.

The technology for long-distance transmission of district heat is first of all an extension of present technology, but some new developments are promising improved economic feasibility, thus extending the practical transmission distance. Some advanced concepts will undoubtedly be applied within the next few years as longer transmission lines are being built.

6.1.1 Culvert and trench systems - Large diameter pipes in concrete culverts are an extension of current practice as described in Chapter 5.1. The largest steel pipe diameters that are expected to be available in Sweden in the foreseeable future are 1500 or 1600 mm (about 59 or 63 inches). This size is suitable for the transmission of about 2000 MW(th) at water temperatures of 165/65°C. Culverts, as shown in Figure 6.1.1.1, are a large version of those shown in Figure 5.1.3 and 5.1.4 and are currently used for pipe diameters up to 800 mm (about 32 inches).

Three alternatives are being evaluated for the transmission line from the Barsebäck nuclear plant to the cities of Malmoe and Lund (Fig. 6.1.1.2 and 6.1.1.3). The "conventional" buried culvert is more expensive than the other alternatives. The open trench alternative is not the least expensive possibility but it is probably the most desirable choice, since the pipe will be hardly noticeable from the nearby highway. The pipe diameter is 1200 mm (about 47 inches) and the planned transmission capacity is 950 MW.

The open trench design has a noticeable similarity to an oil pipeline, particularly to the insulated Trans-Alaska oil pipeline. Obviously the construction technology is the same for both oil and hot water lines.

6.1.2 Rock tunnels - The geology of the Stockholm area is favorable for the excavation of rock tunnels for heat transmission lines, and the construction technology for rock tunneling has been developed to a high level in Sweden. There are now about 20 km (12 miles) of rock tunnels excavated in Stockholm with pipelines installed. Tunnel cross sections vary between 12 and 20 m^2 (about 130 and 220 ft^2). The largest pipe sizes used are 1000 mm (about 39 in). Figure 6.1.2.1 shows a view of such a tunnel. The planned inter-municipal distribution network for the greater Stockholm region comprises about 75 km (47 miles) of transmission pipes up to 1600 mm (63 in.) in diameter in rock tunnels. Figure 6.1.2.2 illustrates the planned systems.

South of Stockholm, the small nuclear heat and power plant of Ågesta, in operation since 1964, is built underground in rock. The planned large reactor station indicated in Figure 6.1.2.2 will also be placed in rock and the transmission pipeline will be in a rock tunnel. This is considered desirable and feasible in Sweden.

The advantages of rock tunnels are that they do not interfere with existing utility lines and they can be excavated under the city without blocking streets. They can be routed in straight lines and they allow ready accessibility for inspection and maintenance of the pipes.

6.2 Advanced concepts.

In the planning of large capacity, long distance heat transmission systems, new concepts for more economical solutions are being advanced and some are being tested in Sweden. Much of this work is being done at the Studsvik Research Center.

6.2.1 Directly buried pipes - In this concept the large water transport pipes are placed in a ditch without culvert. The pipes are insulated and surrounded by a well draining fill. Drain tiles at the bottom of the ditch prevent water accumulation. Figure 6.2.1.1 illustrates the concept.

Alternate pipe materials to replace steel are also being investigated. Reinforced (prestressed) concrete with a plastic, corrosion protecting lining shows promise. Fiber reinforced plastics are also being considered. Both concepts promise long service life due to their corrosion resistance.

6.2.2 Water filled tunnel - Tests have been started to evaluate the possibility of using a rock tunnel as the water carrying conduit. With the large diameter of a tunnel, the insulation requirements diminish, because the relative heat losses become small. Sealing the tunnel walls against leakage may be necessary.

A potential problem connected with the transport of hot water in a rock tunnel was observed in a test by USACRREL in 1968. Thermal stresses in the tunnel walls may cause spalling and progressive collapse. This problem was pointed out to personnel of Stockholm Energy Works and a copy of the test report was provided to them.

6.2.3 One-way hot water transport - In coastal areas and along rivers it is possible to consider one way hot water transport with discharge of the used water into the open water body, thus eliminating the return pipe (Figure 6.2.3.1). Discharge temperatures are similar to those of a conventional power plant.

This concept depends on the efficient utilization of the hot water to minimize the discharge temperature. In this connection, the Studsvik Research Center is developing radiators and convectors for building heating systems that can utilize low temperature hot water in the range of 60 to 40°C (140 to 104°F). Such low temperature hot water would be distributed separately from the regular hot water and sold at a lower energy price.

6.2.4 One-way underwater pipe - This concept is also applicable to coastal areas. Hot water from a large (nuclear) plant is piped to city distribution systems through a submerged plastic pipe. Such pipes are already in use for wastewater discharge lines. They are fabricated on site, floated into position and sunk by concrete weights. For large transport distances intermediate pumping stations can be used to minimize the line pressures. Figure 6.2.4.1 illustrates the concept.

The water temperature must be relatively low in such a system due to strength limitations of the plastic pipe and heat losses to the surrounding water. Water temperatures of not more than 95°C (203°F) are considered. The water supplies the base load for a district heating system and the temperature is sufficiently high for this purpose. For peak demand, temperature topping heating plants in the distribution system provide the required additional capacity.

6.3 Feasibility of long distance transmission - Very few long distance transmission systems have been installed to date. Most of the engineering work so far has been concerned with planning and development. Therefore, only little information is available on costs and economic feasibility. The following information was obtained in Sweden.

The cost of the planned hot water transmission line from the proposed Haninge nuclear heat and power plant to the distribution network in greater Stockholm is expected to be $5000 per meter for four pipes 1600 mm (63 in.) in diameter. The cost of the tunnel is additional.

The cost of the transmission line from the Barsebäck nuclear plant to the cities of Malmoe and Lund is estimated to be $55 million for an open trench configuration. This line consists of 13 km (8.1 miles) of 1200 mm (47 in.) diameter supply and return pipes, 13 km (8.1 miles) of 1000 mm (39 in.) pipes and 4 km (2.5 miles) of 500 mm (20 in.) pipes. The cost of the individual lengths is not given but an estimate can be made. The whole pipeline consists mainly of two equal length sections of 1200 mm and 1000 mm pipes and their cost is about $2000 per meter for 2 pipes. This is close to the general reference figures of $1000 per meter for 1000 mm pipe, given by Mr. P. Margen, Chief Engineer, at the

Studsvik Research Center. At Studsvik, the economic feasibility of long distance heat transmission with hot water has been analyzed for various conditions. Figure 6.3.1 shows the estimated cost of heat produced at a nuclear heat and power plant as a function of transport distance. The cost of locally generated heat from oil is given for reference. The 2000-MW line is feasible over a greater distance than the 200-MW line, as might be expected. In each case, the higher costs are associated with the pipe in buried culvert system and lower costs with the open trench system. For shorter distances a lower supply temperature is feasible for direct feeding into the distribution system. For greater distances a higher supply temperature is economical and a heat exchanger is used to connect to the distribution system. The heat exchanger serves the corresponding function of a transformer in an electrical transmission system.

In Figure 6.3.2 the economic feasibility of some advanced concepts is illustrated. The heat transmission costs with buried glass fiber reinforced plastic pipes or plastic lined prestressed concrete pipes are shown to be lower than with conventional steel pipes. For shorter distances a two-way pipe is feasible (supply and return), for greater distances a one-way pipe carrying sea water and connecting to a heat exchanger is feasible. The analysis is based on a transmission capacity of 200 MW and an annual utilization of 5300 hours (7-1/4 months).

The supply temperature for long distance heat transmission is increased for greater distances. It is found that this is economical because it reduces the pipe size for a given transmission capacity, even though it increases the cost of the delivered heat. The highest water supply temperatures used in Europe are 180°C (356°F). Figure 6.3.3 illustrates these relationships.

The conclusion from this information is that long distance heat transmission from remotely located nuclear heat and power plants to urban district heating systems is feasible for distances of 100 km (62 miles) and beyond at current oil prices. With rising oil prices, as expected in the future, such long distance transmission becomes an increasingly important planning consideration. The currently available technology is suitable and improved designs will probably make it even more attractive in the future.

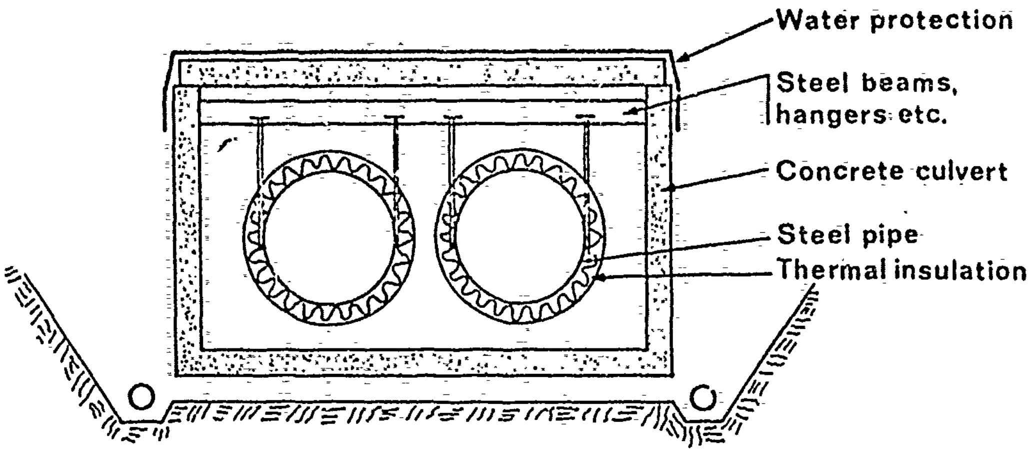


Figure 6.1.1.1: Typical conventional pipe in culvert heat transmission system. The culvert has drain pipes on the outside at its base for ground water control.

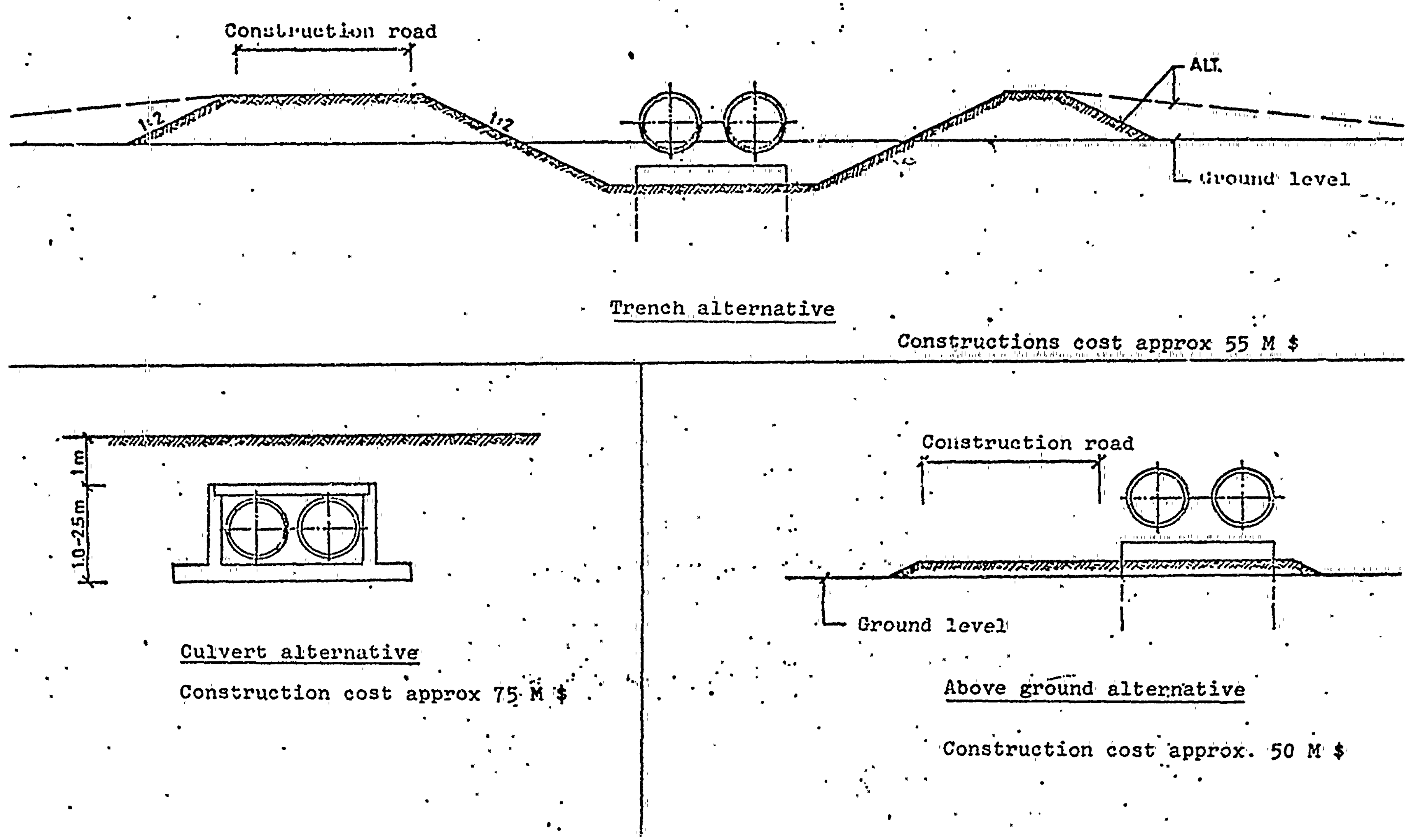


Figure 6.1.1.2: Three alternatives for the proposed long distance heat transmission line from the Barsebäck nuclear plant to the cities of Malmoe and Lund.

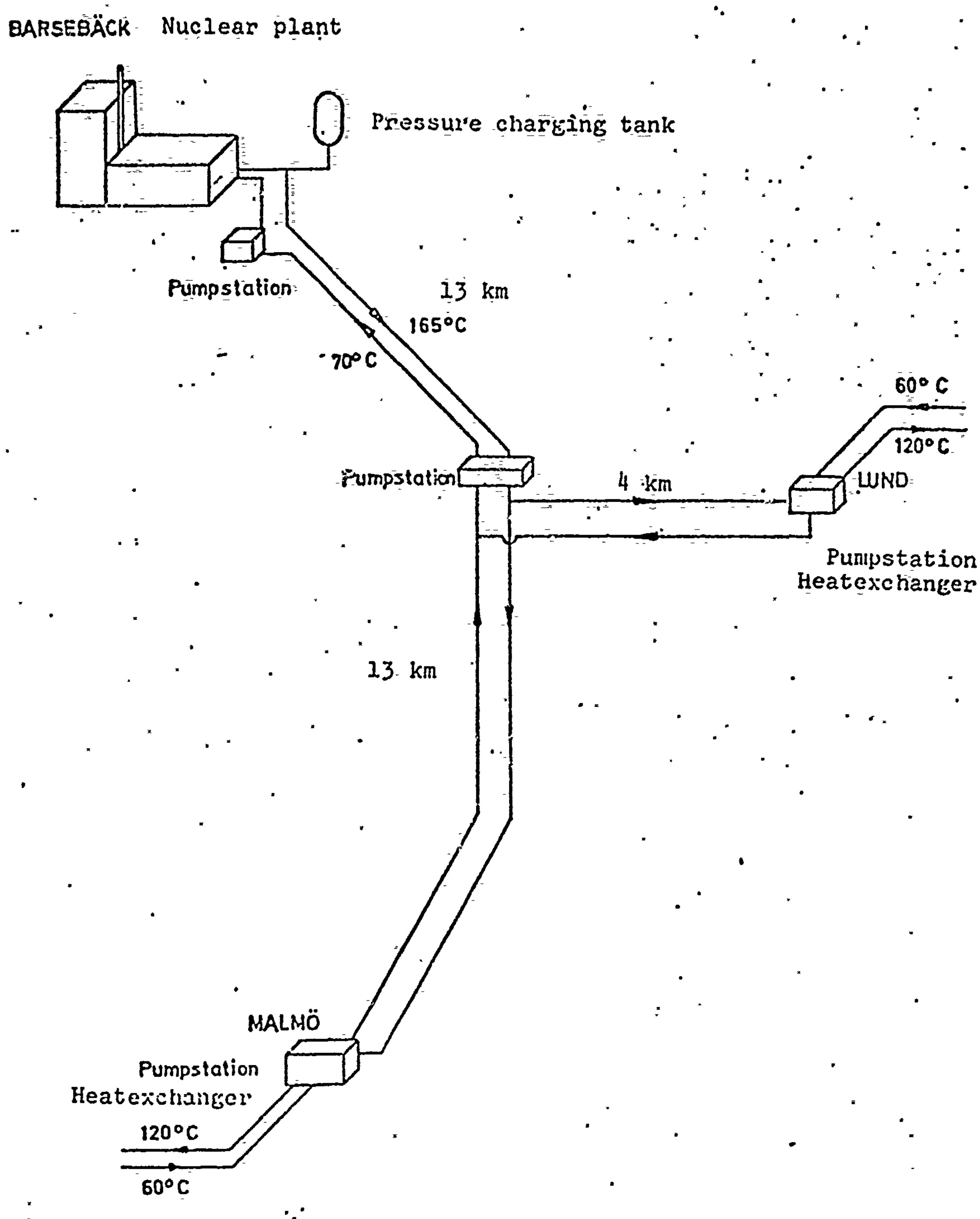


Figure 6.1.1.3: Principal layout of the proposed long distance heat transmission line from Barsebäck to Malmoe and Lund.

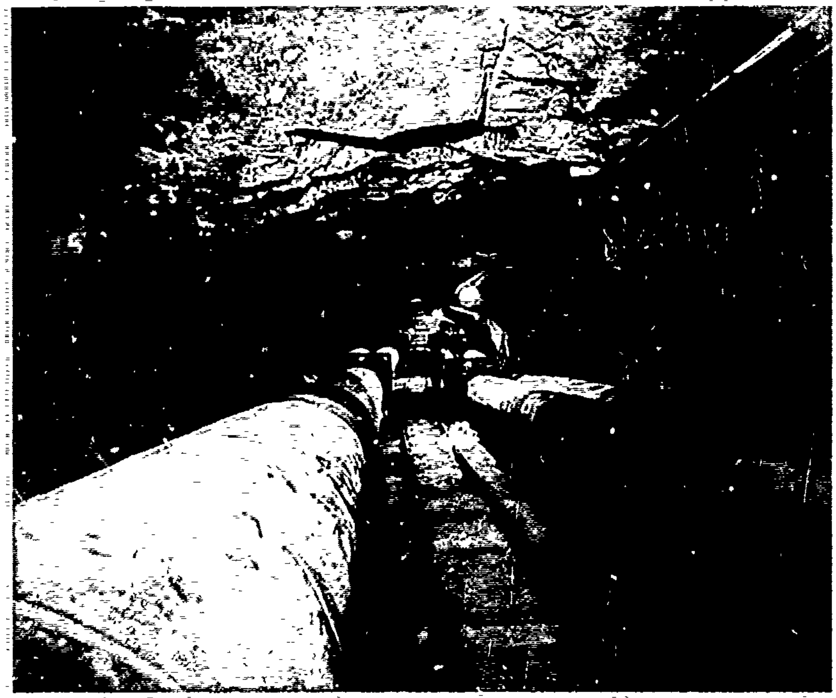


Figure 6.1.2.1: Main hot water distribution lines in rock tunnel in Stockholm.

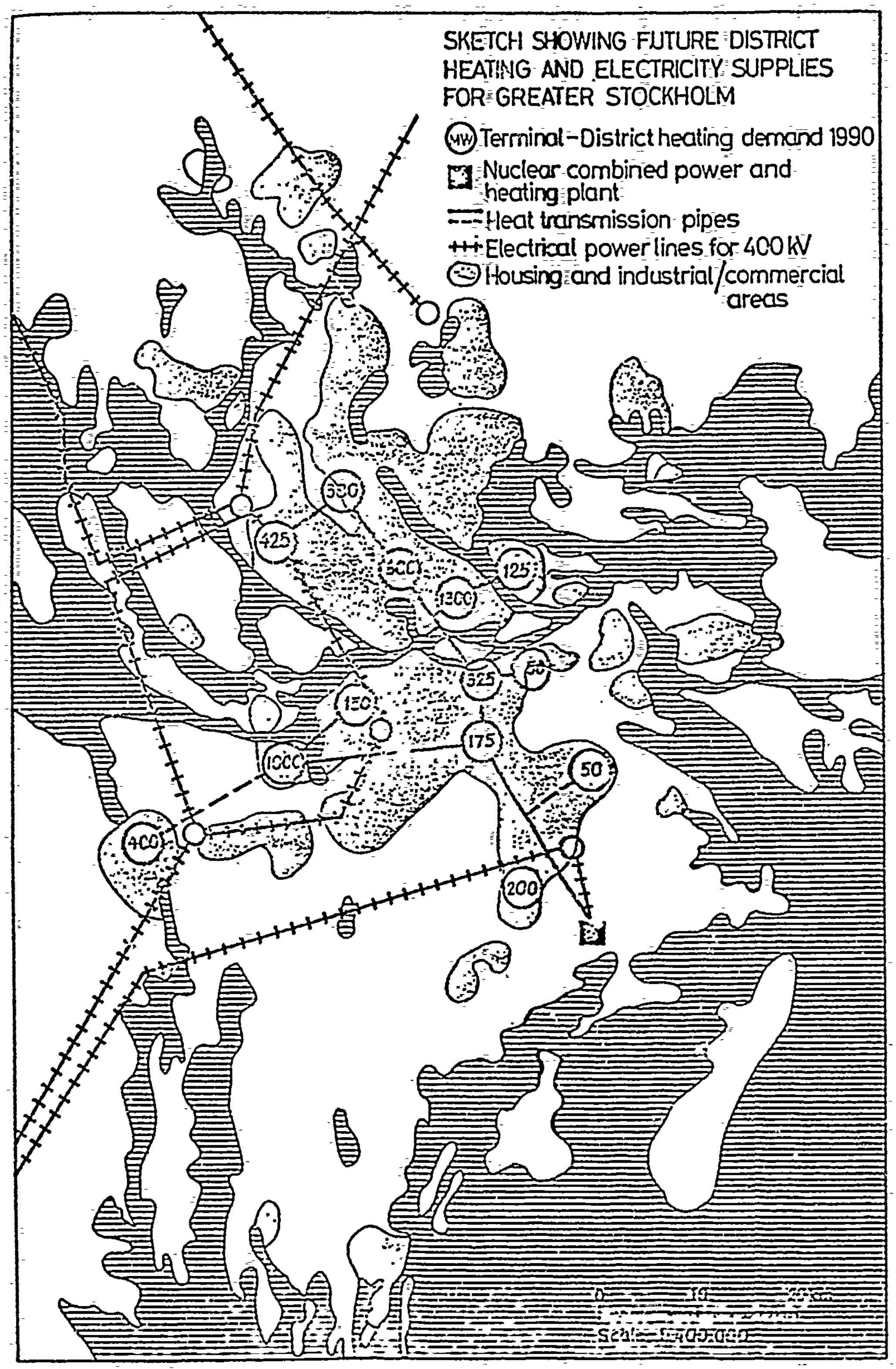


Figure 6.1.2.2: Planned inter-municipal distribution network for heat and electricity in greater Stockholm.

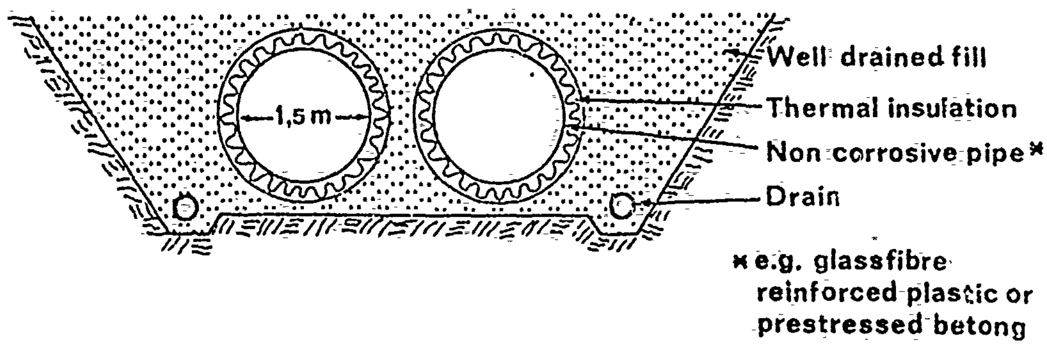


Figure 6.2.1.1: Directly buried large hot water transport pipe concept. The fill material is covered with a rain shield (not shown) to prevent wetting.
Problem areas:

a. Rubber ring seal quality.
b. Forces at bends and valves.
c. Internal protection of the pipe surface, if concrete.
d. Thermal stress in the pipe.

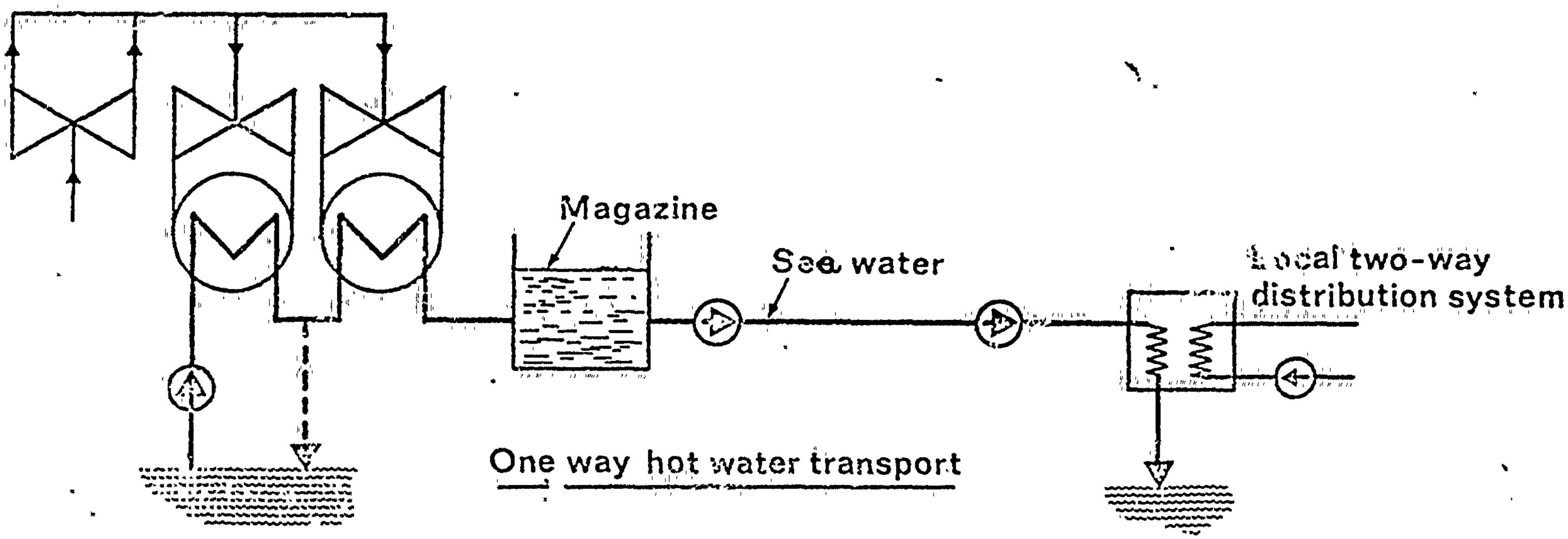


Figure 6.2.3.1: Schematic diagram of a one-way hot water transportation scheme, applicable for long distances and low return temperatures. The pipe material must be corrosion resistant (e.g., plastic coated or lined concrete).

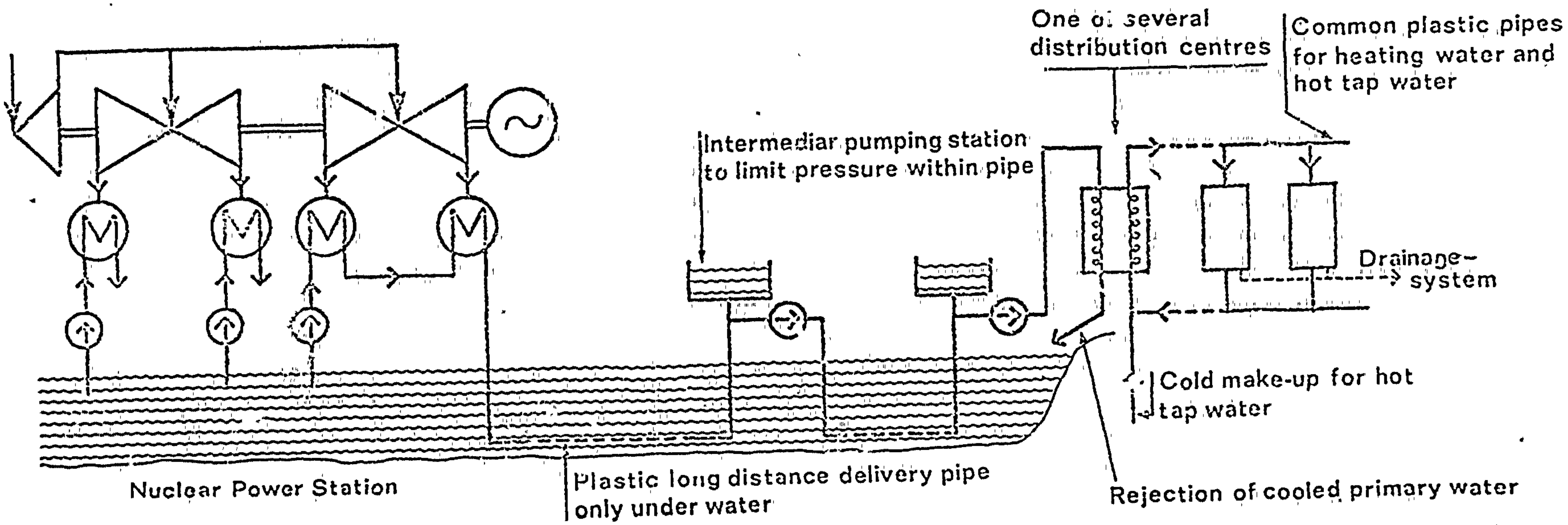


Figure 6.2.4.1: Schematic diagram of a one-way underwater pipe system. The water temperatures in the pipe are low enough to permit the use of plastic pipe and to avoid excessive heat losses.

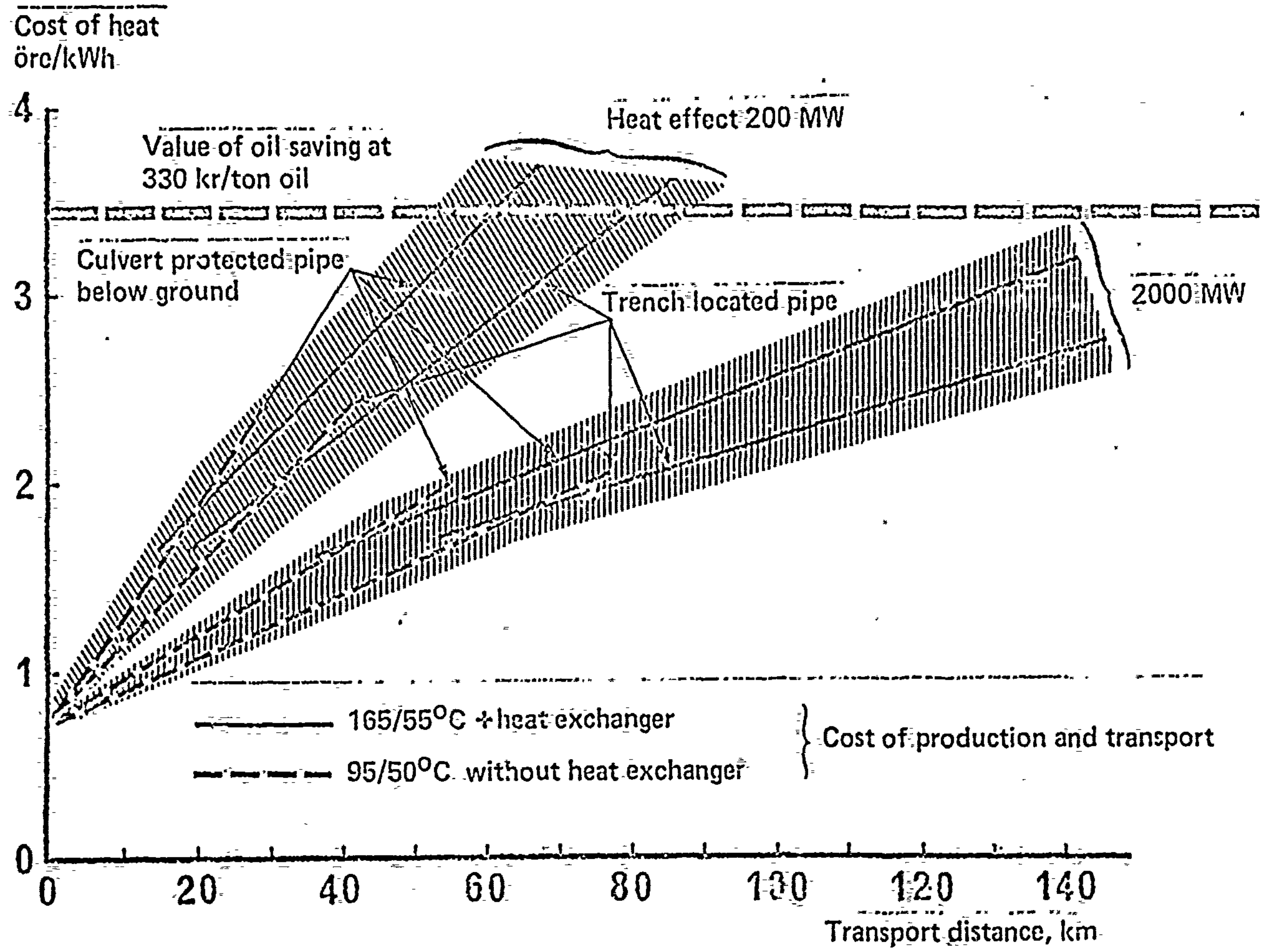


Figure 6.3.1: Cost of heat production in a nuclear heat and power plant and long distance transport with conventional technology (5300 h/year base heat load)

(Note: 1 US ¢/kWh = 4 ore/kWh, about)

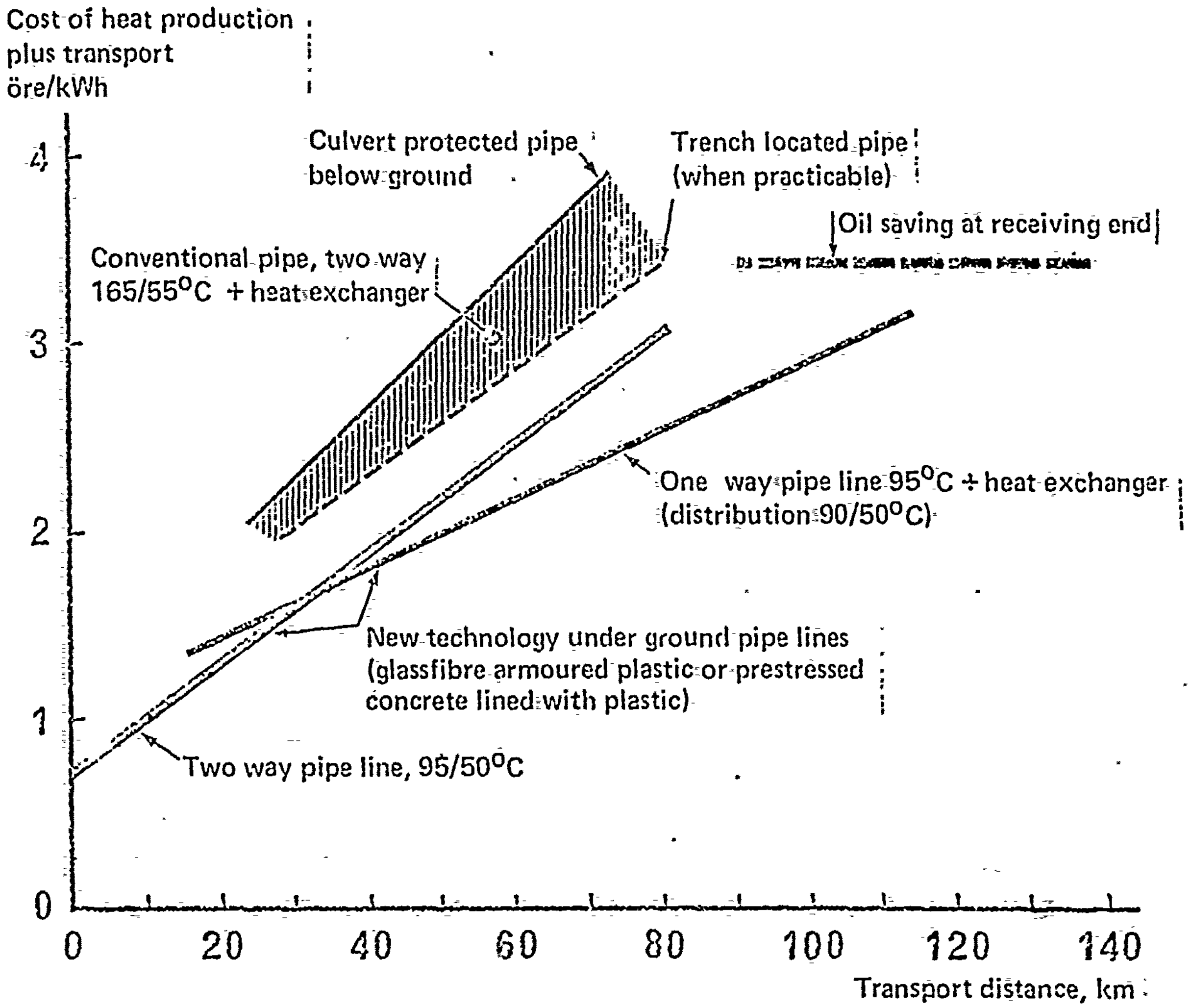


Figure 6.3.2: Cost of heat production and transport with new technology under development

(Note: 1 US ¢/kWh = 4 ore/kWh, about)

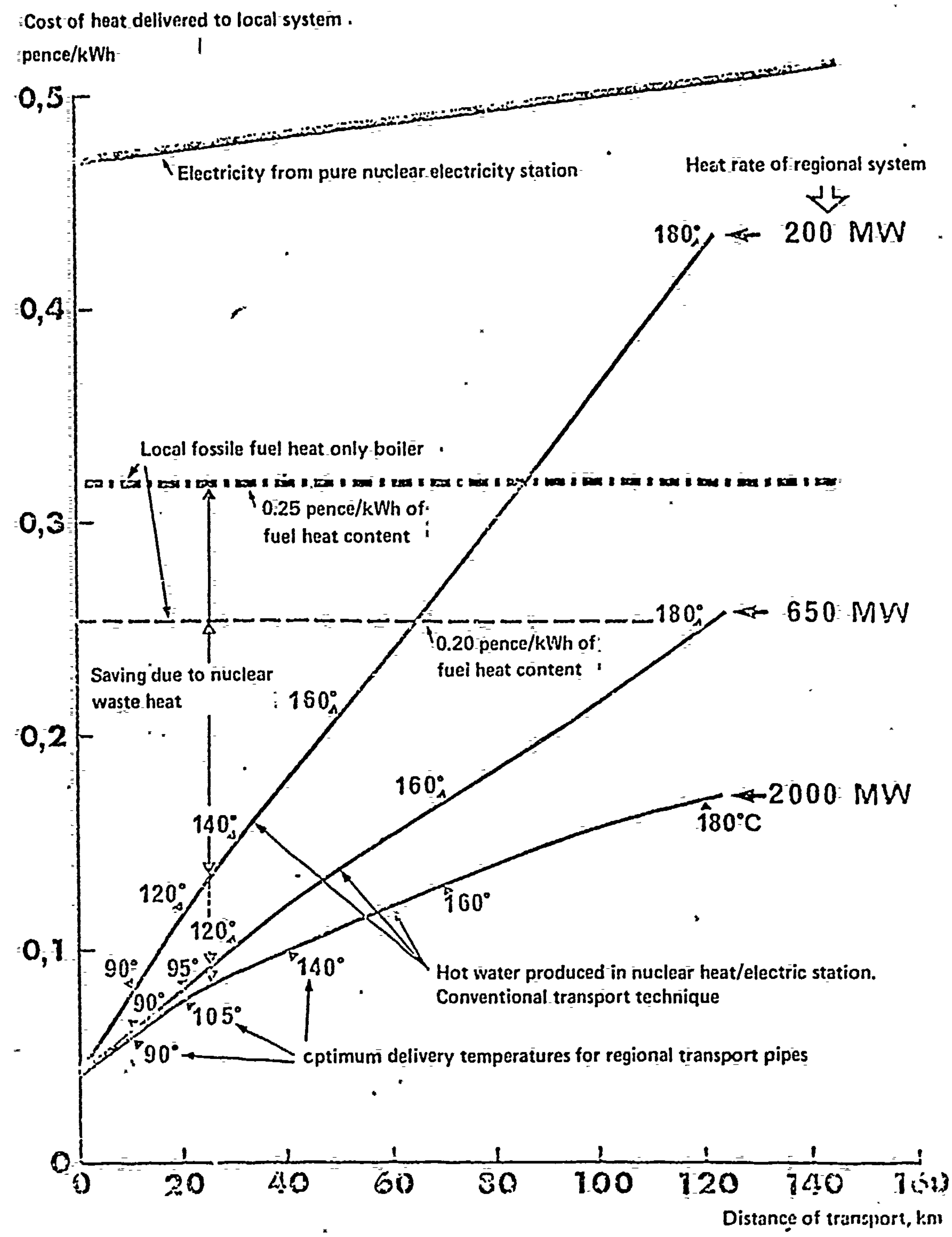


Figure 6.3.3: Cost of heat from regional network of conventioal pipes at optimum delivery temperature as function of transport distance (base load part 5300 h/year, return water temp = 60°C)

(Note: 1 US ¢/kWh = 0.4 pence/kWh, about)

REFERENCES

Chapter 1 - Water Distribution Lines
Chapter 2 - Sewage Transport Systems
Chapter 3 - (No References)

1) Brekke, T.L. and F.A. Joorstad (eds) 1969 "Large Permanent Underground Openings" Proceedings of the ISRM symposium Sep 23-25 1969 Oslo Norway Universitetsforlaget.

2) British Standard Institution -- Code of Practice

   a) Engineering and Utility Services (CP 3 Ch VIII)
   b) Frost Precautions for Water Services (CP 99)
   c) Building Drainage (301)
   d) Small Sewage Treatment Works (CP 302)
   e) Cesspools (CP 302, 200)
   f) Sanitary Pipework above Ground (CP 304)
   g) Water Supply (CP 310)
   h) Hydrant Systems (CP 402.101)
   i) Sprinkler Systems (CP 402.201)
   j) Ducts for Building Services (CP 413)
   k) Site Investigations (CP 2001)
   l) Earthworks (CP 2003)
   m) Sewerage (CP 2005)
   n) Des. and Construction of R&PSC Structures for the Storage of Water and other Aqueous Liquids (CP 2007)

      Imperial Units (Pt 1)

      Metric Units (Pt 2)

   p) Installation of Pipelines in Land (CP 2010 Pt1)

      Design & Construction of Steel Pipelines in Land (Pt 2)

      Design & Construction of Trans Pipelines in Land (Pt 3)

      Design & Construction of A/c Pipelines in Land (Pt 4)

3) British Steel Corporation Tubes Division:

   a) Steel Pipes for Water Mains

4) Collins, S.P. 1972 "Three Valleys Aqueduct in Tunnell", Tunnels & Tunnelling Sept 1974 P 441-445 London.

5) Cuthbert and Wood 1962 "The Thames-Lee Tunnel Water Main", Proceeding of the Institute of Civil Engineers Vol 21 p. 257-276. London.

6) Gundersen, Per 1974 "Frost Insulation of Pipe Trenches" Frost Journal No. 13, Committee on Frost action in Soils, Gustadellein 25 Oslo 3, Norway.

7) Gundersen, Per (1975, "Frostproofing of Pipes" Norges Teknisk Naturvitenskapelige Forskningrad Utvalg for Frost I Jord Oslo Norway (In Norwegian).

8) Hellstrom Bo, and Erling Reinius 1963. "The Hydraulic Laboratory at the Royal Institute of Technology Stockholm" Bulliten 63 of the Div of Hydraulics at the Royal Institute of Technology, Stockholm Sweden.

9) Jaeger, J.C. 1969 Elasticity, Fracture and Flow, 3rd Ed. Methuen and Co. London.

10) Janson, Lars Eric and Pentti Valma 1974 "Some Investigations concerning VPVC Water and Sewer Pipes and Fittings", Journal of American Water Works Assn. Vol 66 No 6 June 1974.

11) Janson, L.E., 1974 "The Freezing Risk for Water Mains in Frozen Ground" Frost Journal of the Committee on Frost Action in Soils, Gaustadelleem 25, Oslo 3, Norway.

12) Janson, L.E. 1972. "Guide for Determining the Laying Depth for Water Pipes in the Ground with Reference to Frost" Svenika Valten-Och Avloppsverksforeningem Regerinsgaten 86 Stockholm Sweden (In English).

13) Janson, L.E. 1972 Case Study 4 Practical Experience with Buried Sewer Pipes - Proceedings 2nd International Plastic Pipes Symposium, Southhampton England Sept 1972.

14) British Government Publications:

a) The Water Act - 1945
b) The Water Act - 1973
c) Health and Safety at Work Act 1974
d) Model Byclaws Water (Waste etc. Prevention) 1966
e) D.O.E. Report No. 17 The Bacteriological Examination of Water Supplies 1969
f) B.R.S. Simplified Tables of External Loads on Buried Pipelines
g) D.O.E. Reinstatements under the Public Utilities Street Work Act 1950 - A Model Agreement and Specification 1974
h) D.O.E. Report of the Committee on Bachsipjarage in Water Installations 1974
i) D.O.E. Work Party on Sewers and Water Mains 1st Report - 1975

15) Thames Water Authority - Metropolitan Water Division

a) M.W.B. contract for Pipelaying, Repairs, Alternations, etc.
b) City University A Survey of Fractures in Grey Cast Iron Water Mains

16) Institution of Water Engineers

a) Panel 12 Organization and Procedure for Maintaining Records of Distribution Mains 1973
b) Panel 13 Experience with the Cathodic Protection of Mains 1973

17) British Cast Iron Research Association

a) Soil Corrosion Resistance of Grey and Ductile Iron Pipe - A review of available information A.G. Fuller 1972

18) Pequignot, C.A. 1965 "Chunnel - (Channel Tunnel), "C.R. Books Ltd London England.

19) Rabcewicz, L.V. 1969 "Stability of Tunnels Under Rock Load" Water Power Part I. June 1969 p. 225-299 Part II July 1969 P. 226-273 Part III Aug. 1969 p. 297-302.

20) Rabcewicz, L.V. 1964-65 "The New Austrian Tunneling Method" Water Power Vol 16 (11) 453-357; Vol 16 (12) p. 511-516; Vol 17 (1) 19-25.

21) Reed, E.C. 1972 "Coppermills Filtration Works and Pumping Station" Metropolitan Water Board, London, England.

22) Sgechy, K. 1966 "The Art of Tunneling" Akademiai Kaido, Budepest Hungary Translated from Hungarian.

23) Tattersall, Wakeling and Ward 1956 "Investigation into the Design of Pressure Tunnels in London Clay" Proceed of Institute of Civil Engineering 4 P 400-455, London.

24) Vivian, C.H. 1973 "Kanats" Compressed Air Magazine Jan 1973, P. 16-18.

25) "Mini Tunnels International Ltd. 1974" Design Operations. Specifications Westminster House, Old Woking Surrey, England.

Chapter 4 - Electrical Transmission

1) Stockholm Electricity Supply Authority, 1973 report.

2) Aerial Lines and Cabl . - A Revolution in Distribution Networks T.J. Hafsted, EFI, No.4, December 1974, Volume 14.

3) Heavy ice and snow loads on conductors and towers in the Mountain Districts of Norway, T. Horn, Meeting of CIGRE, Paris, 6 June 1964.

4) Icing on Overhead lines in Norway, E. Olaussen, EFI (The Norwegian Research Institute of Electrical Supply) Technical Report No. 1829, June 1974.

5) South Bank District Heating Scheme, N.J. Holt, London Electricity Board, 1973 Commercial Conference, Sep.

6) An Integreated System of Metropolitan Electricity Supply. A.G. Milne and J.H. Maitby, Proceeding of the Institute of Electrical Engineers, Vol. 114, No. 6, June 1967.

7) Electrical Supply in Sweden 1975-1990, 1972 study, Central Operating Management, Stockholm, Sweden.

8) SyDKAFT 1973, Annual Report, The Sydkraft Group, Sweden.

9) LIDON accessories for self-supporting aerial cables type ALUS; Liljeholmens Kabel, February 1971 (in Swedish).

10) Standards for aerial cables, 0.4 KV, type ALUS; Swedish Power Companies Association, June 1973 (in Swedish).

11) Overhead lines or underground cables: The problem of electrical power transmission, Endeavor Vol XXXIV No. 121 Jan 1975

Chapter 5 - District Heating

1) The District Heating Association LTD, Annual Handbook 1973/74.

2) District Heating Power, STAL-LAVAL Turbin AB, Sweden.

3) District Heating and Telethermics - new data on Heat Mains, A.E. Haseler, B5E, Feb. 1975, Volume 42.

4) Thermally Insulated Underground Piping Systems, British Standard Code of Practice, CP3009, 1970.

5) Heat on Tap from the Mains, A.E. Haseler, Department of the Environment, England, Building Installations and Services, May 1971.

6) New Heat Mains Techniques for Telethermics, E.A. Haseler, Department of the Environment, England, Instn. Heat Vent. Engrs J, Dec 1970.

7) The Coherent Thermal Mains Systems, A.E. Haseler, Department of the Environment, British Government.

8) New Techniques for Telethermics: their critical importance for conservation and the environment, E.A. Haseler, 63rd Annual Conference of the International District Heating Association, June 1972.

9) Mathematical System for Calculation of Spread of Air Pollution in the Greater Stockholm Area, First Stage Study: Stockholm City Area, B. Bringfelt and O. Wikström, Stockholm Electricity Board, May 72.

10) Malmö Kraftvärmeverk (City of Malmö, Power Heat Division, 1973.)

11) District Heating, Stockholm Electricity Board, S-10432 Stockholm 19.

12) District Heating, City of Linköping, Brochure Published, Technical Works City of Linköping, Sweden.

13) District Heating Thermal Power Heat Station, City of Västerås, The Swedish District-heating Works Association, May, 1972.

14) Hasselby Power and District Heating Station, I. Wernius, Teknisk Tedskift, Vol 24 Feb 1961.

Chapter 6 - Long Distance Heat Transmission

1) District Heating for the Barsebäck Nuclear Power Plant, UNICHAL Conference, September, 1975.

2) District Heating - New Opportunities with New Techniques, P.H. Margen, Studsvik Research Center, May 1973.

3) The Future Trend for District Heating - Regional Nuclear District Heating Schemes and Improved Heat Transport and Distribution Techniques, P.H. Margen, Talk given at DHA (London) and BNES, May 1974.

4) Nuclear Reactors for District Heating, P.H. Margen, Studsvik Research Center, March 1975.

5) Nuclear Energy for Domestic Heating, 13th Nuclear Energy Conference in Milan, December 1974.