# DISTRICT HEATING AND COOLING

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## Development of District Heating in Buffalo

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# DHC and Diplomacy: *How One U.S. Military Village Linked Up With Its German Neighbor*

**About the Authors:**
Max Matejka, and Volker Ritter, IWK Regler und Kompensatoren GmbH, Stutensee, with Dietrich Homburg and Ellen-Christine Rieff, Redaktionsbüro Stutensee.

When a small U.S. military community 'tied the knot' last year with the municipal energy system of a nearby German city, no world-wide headlines or international ceremonies marked the occasion. But the agreement between the U.S.'s Paul Revere Village and local officials of Karlsruhe in the Federal Republic of Germany held its own significance. The U.S.'s "home away from home" would be heated by a method rare in residential areas in the States: district heating.

District heating, of course, is no stranger to the United States. New York City has had a district heating network since 1882. But most DHC systems in the U.S. supply heat for public buildings and businesses; private homes must depend on other energy sources. In Germany, however, heavy state subsidies have given the country a thirty-year tradition of supplying its energy needs—public and private—through massive district heating systems.

**A Tradition of Efficiency**

Karlsruhe, a city on the northern edge of the Black Forest, was among the pioneers of district heating. As early as the turn of this century, the steam boiler plant of the Ducal Water Works was used to supply electricity and district heating to the Karlsruhe Palace (Fig. 1) and its neighboring administrative buildings. Today, Karlsruhe has a modern district heating network which extends over more than 90 km and is being expanded constantly. More than 12,000 homes and roughly 1,000 businesses and public buildings are linked up to it, with a connected load of approximately 350 MW. At the same time, Karlsruhe's combined heating and power stations generate one-quarter of the city's total electricity requirements and could supply roughly a further 30,000 homes with district heating for room air conditioning and service hot water generation; this would be equivalent to roughly one-third of the whole city.

In the Federal Republic as a whole, approximately 8.5% of all homes are currently heated by district heating. Plans call for an increase of this figure to approximately 25% by the year 2000. Roughly 75% of the district heat required is to be taken from heat and power stations (combined heat and power), 22% from heating plants, and roughly 3% from industrial waste heat (steam). Heating and power stations with combined heat and power are becoming increasingly popular in the Federal Republic because of their high level of economic viability and optimal energy efficiency. In Karlsruhe, combined generation of electricity and dis-

*continued on page 21*

Photo: Bildstelle der Stadt Karlsruhe

*The palace in Karlsruhe, begun in 1715, and the neighboring administrative buildings have been heated by district heating since the turn of the century.*

## DHC and Diplomacy

*continued from page 19*

trict heat started with the conversion of the city's electricity generating station into a heating and power station in 1963.

Combined heat and power stations utilize fuel efficiently. While power stations in which the heat generated is not used only exploit about 40% of the energy generated, (Fig. 2a), the corresponding figure for heat and power stations is around 85% (Fig. 2b). A power station used solely to generate electricity gives off its waste heat to the environment unused. (cooling water, surrounding air). If a district heating network exists or can be constructed, however, then a large proportion of this waste heat can be exploited for district heating. The quantity of usable heat thus transferred to the district heating network is more than double the additional primary energy expenditure. In areas with a heat density of 20 MW/sq.km or more, the economic and ecological advantages of district heating from combined heat and power are enormous:

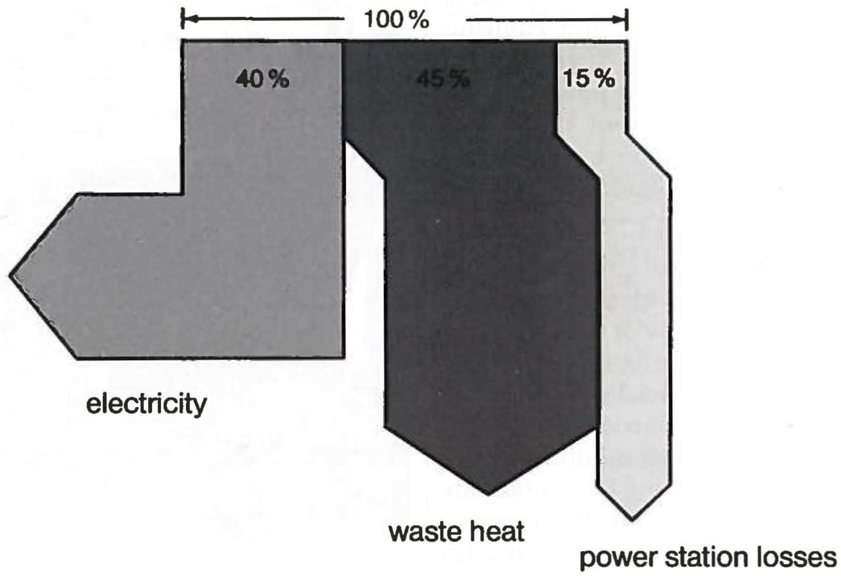
- Favorable cost-benefit ratio
- The ultimate consumer is not dependent on the type of primary energy source used. In times of crisis the utility company can, given appropriate technical design, fall back on whichever is the most inexpensive source of primary energy available at that time. Oil imports can be reduced.
- Pollution in densely populated areas is drastically reduced. Levels of both emission and intromission are lowered significantly. In contrast to many individual hearths with relatively low chimneys, the single high stack of a heat and power station will guarantee greatly reduced levels of intromission even during the most unfavorable weather conditions, i.e., inversion.

### Linking the Village to the City

The above reasons also persuaded the Karlsruhe city administration and the administration of the American Paul Revere Village to connect the community, located at the northwest

**FIGURE 2a**

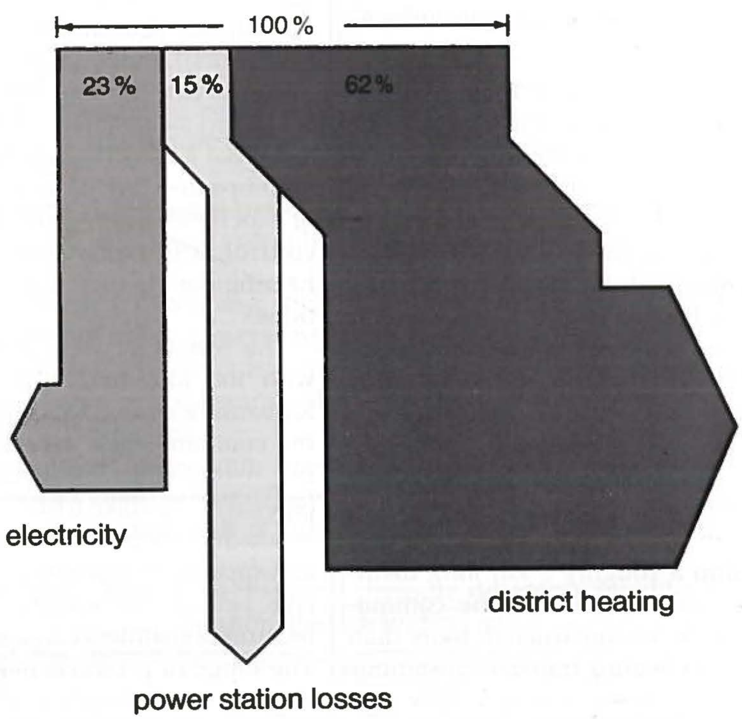
condensing turbine power station (electric generation only)
fuel utilization




degree of energy utilization = 40 %

**FIGURE 2b**

power station (combined heat and power)
fuel utilization




degree of energy utilization = 85 %

Drawing: Stadtwerke Karlsruhe

*Conventional power stations only exploit around 40% of the primary energy used (a), while combined heat and power stations attain a degree of energy utilization of around 85% (b).*

boundary of the city, to the municipal district heating network. Before construction work began, Charles E. Williams, the District Commander, Major Floyd F. Griffin, head of the US Directorate of Engineering and Housing, and Bernhard Blank, director of the municipal heating and power station, repeatedly pointed out the advantages that connection to the district heating network would have for the community:

- The elimination of 250 obsolete boilers means a considerable reduction in environmental pollution. The ecological benefit is enormous: according to official estimates, 140 tons less sulfur dioxide, 34,000 tons less carbon dioxide, and 75 tons less dust are now being blown into the atmosphere per year than before.
- Thanks to district heating, the US garrison in Karlsruhe is saving more than $1.5 million a year in energy costs.
- There were no problems in adapting the existing central heating systems and radiators to the new heat supply. There are no longer any boiler maintenance costs to be borne. The contractually agreed heating tariff for district heating includes all maintenance costs.

Investment finance for the project was provided by the City of Karlsruhe and, at the wish of the American community, it was implemented with extraordinary dispatch by the municipal administration and the companies involved. Less than five months passed between turning the first sod (Fig. 3) for pipeline construction work on May 11, 1984, and commissioning of the system on October 1 of the same year. District heating for the Paul Revere Village was thus assured for the 1984/85 heating period. To achieve this aim, a 630-meter long main trunk line and a roughly 5 km long distribution network within the community had to be constructed. More than 80 district heating transfer substations with a connected load of 35 MW supply heat for room air conditioning and service hot water generation to more than 1,000 homes in 70 apartment houses, as well as to a school, a church, a kindergarten, a shopping center, a self-service store, a cinema, and a restaurant.


*The start of construction work on the district heating lines for the US residential community Paul Revere Village.*

Both the control equipment in the supplier's and the consumer's substations, as well as the expansion joints (Fig. 4) required for the pipeline were furnished by IWK Regler und Kompensatoren (Controllers and Expansion Joints) GmbH, a company located near Karlsruhe. The medium-sized company, a subsidiary of the "Industriewerke Karlsruhe Augsburg" group of companies (IWKA), has had decades of experience in the field of metering, control, and expansion joint engineering for district heating applications.

The history of IWK starts in 1872, with the founding of a factory on Karlsruhe's western city limits. In 1898, the company took over a patent for the manufacture of "flexible metal pipes with beadlike folds," and started producing metal hoses for industry and apparatus engineering. As a result, IWK became the world's first manufacturer of seamless corrugated hoses. The range of products made by IWK Regler und Kompensatoren GmbH today is still based on this original product. In its modern factory premises the company manufacturers metering and control devices for dis-


*Shut-off valve manhole in Rhode Island Avenue, Karlsruhe. On right, bellows expansion joints to take up longitudinal expansion in the supply and return lines.*

trict heating supply systems and industry, as well as expansion joints and metal bellows for pipeline systems and apparatus engineering, accoutrement engineering, and the automobile industry. Now, in cooperation with an American company, IWK is aiming to take its know-how in district heating engineering into the US market.

### Making the Connection Work

The link between the municipal district heating network and the building heating system is the supplier's substation. Since existing building heating systems now receive their heat from the district heating network, local factors had to be taken into consideration when they were being designed. The municipal network delivers superheated water at a temperature of 266°F and a supply pressure of 180 psi. The return pressure is 60 psi. All three of these values mean that direct connection to the existing heating systems in the community was out of the question. Indirect links were therefore required. With a connection of this kind, the district heating water does not flow directly through the building system, but is separated from the heating system by a heat exchanger.

Figure 5 illustrates the design of these building connections. The supplier's substation is the responsibility of the municipal authorities alone. Main shutoff valves are installed in both the supply and return lines. Supply and return pressures are indicated by two pressure gauges, and two thermometers are provided for checking the supply and return temperatures. The nonreturn valve and the calorimeter (d), the flow regulator and the differential pressure controller (e) are likewise part of the scope of supply of the municipal utility company. The two last-mentioned devices are particularly important and are dealt with in more detail below.

**FIGURE 5**

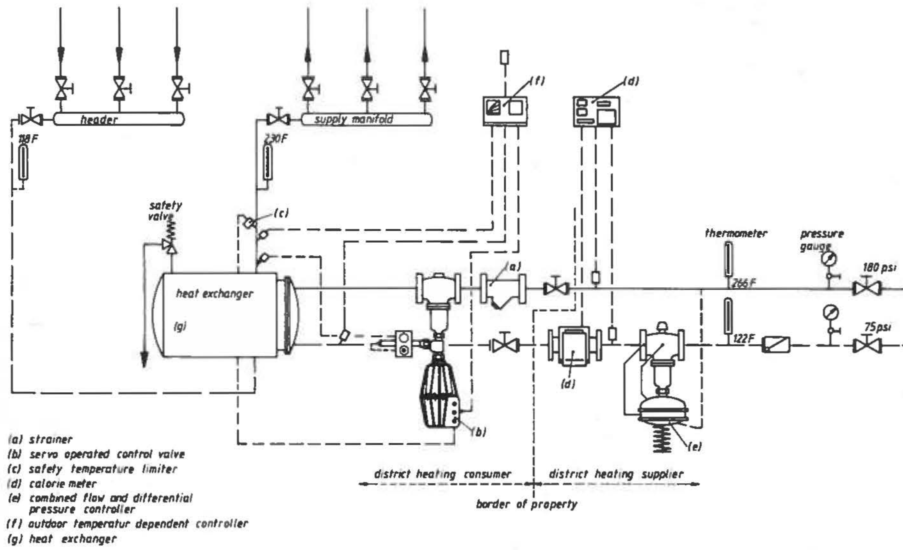



Diagram: Stadtwerke Karlsruhe

*Circuit diagram of building connection. Including the necessary metering and control equipment and the heat exchanger.*

### Specially Developed Values & Controls

The client's section of the substation includes two more shut-off valves, the strainer (a), the servo-operated straight-way valve (b), the heat exchanger (c), the electronic outdoor temperature-dependent heating controller (f), and a series of temperature sensors connected to the latter. The servo-operated straight-way valve (b) controls the volume of heating water supplied to the heat exchanger and thus the temperature of the heating system supply. The valve generates very little noise; this is often a very important consideration in heating systems. Aside from this, it makes multiple control functions possible—a feature that is utilized in the case described here.

The outdoor temperature-dependent heat controller (f) was specially developed for district heating systems. It works as a three-step controller, its output relay generating opening or closing control pulses to the electrohydraulic actuating drive of the straight-way valve (b).

The maximum and minimum supply temperatures in the building heating system can be limited. It is also possible to limit the temperature of the return flow. This is necessary because in the case in question the operator of the district heating network requires a maximum return temperature of 122°F in order to assure economic operation of the network.

The servo-operated straight-way valve is of modular design. The heart of the unit is a valve which is also used for controllers without auxiliary energy. The servo motor drive is attached to the valve via a combination piece. This drive receives its actuating pulses from the outdoor temperature-dependent heating controller. A safety temperature limiter (c) is also provided, which closes the valve if the supply temperature is too high. To enable the heating system to continue in operation during a power outage, an additional thermostatic controller requiring no auxiliary energy supply is installed, which acts directly on the valve via the combination piece.

The flow and differential pressure controller (e) will probably arouse considerable interest on the US market, because to the authors' knowledge devices of this kind are not yet available in the USA. Figure 6 shows a cross section through one of these devices, which performs two functions at once: on the one hand it maintains a constant pressure difference between supply and return; this is necessary because fluctuations in this pressure difference would act on the actuating valve as disturbances. The other task of this device is critical to the functional efficiency of large-scale district heating networks: the flow and differential pressure controller limits the quantity of superheated water taken by each individual consumer to

FIGURE 10

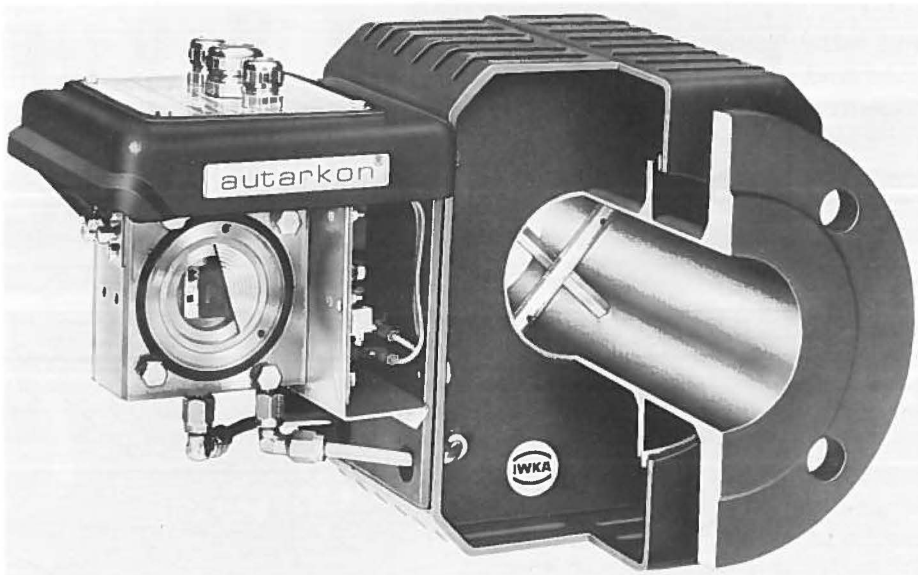



Photo: IWK Regler und Kompensatoren GmbH

*Cross section through the metering section of the autarkon[R] calorimeter with pressure sensors and differential pressure cell.*

the agreed connected load value. Thus, hydraulic balance within the district heating network is also assured. At the same time, the device protects the calorimeter from excessive flow volumes.

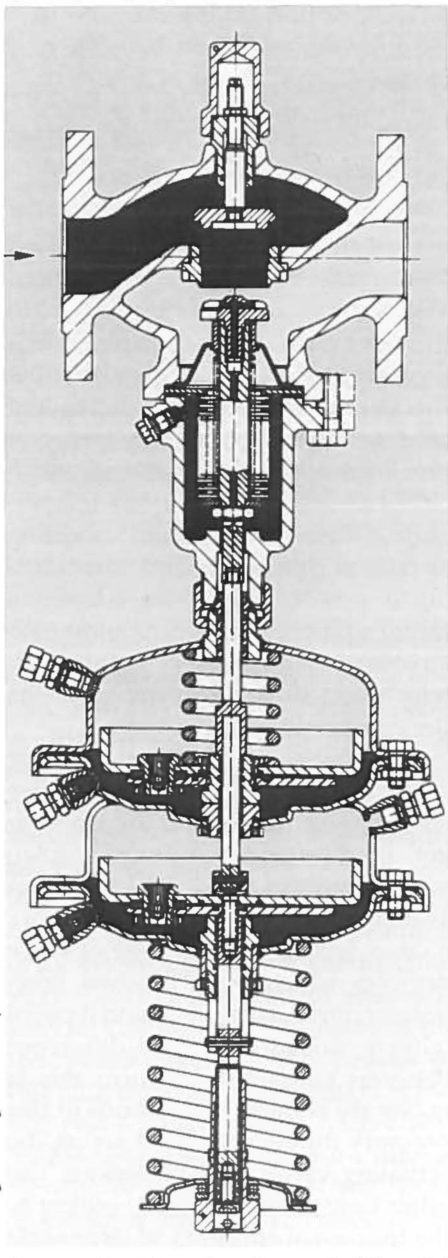
A dependable calorimeter (d) is required in order to charge for the quantity of heat consumed. A device developed by IWK (Fig. 10) is suitable both for compression flow media (e.g., steam) as well as for noncompressible media (e.g., water). It has static metering probes in its flow section; these generate a differential pressure signal which is converted into a flow signal by a piezoresistive pressure sensor. The transducer computes the quantity of heat from the flow and the difference in temperature.

**Compact Substations; A Cost-Saving Alternative**

Compact district heating substations such as those installed in the Karlsruhe district heating network (Fig. 7) represent a cost-saving alternative to conventional transfer substations. They operate either directly or indirectly, i.e., with or without heat exchangers, and are suitable for both individual residences as well as apartment houses. The basic element is a cast duct block, which can be fitted with a strainer, a pressure-reducing valve, flow, differential pressure, and overflow controllers, a safety valve, a safety temperature limiter, an electric actuating drive, nonreturn valve, pressure gauges, thermometers, and an electric heat regulator, depending on requirements.

Compact substations cost less to manufacture than conventional building transfer substations, and take up less space in the building mechanical room. Compact substations thus

FIGURE 6



Drawing: IWK Regler und Kompensatoren GmbH

*Cross section through a flow and differential pressure controller. It maintains the pressure difference between supply and return flows constant and limits the heating water flow volume to an adjustable maximum value.*

FIGURE 7

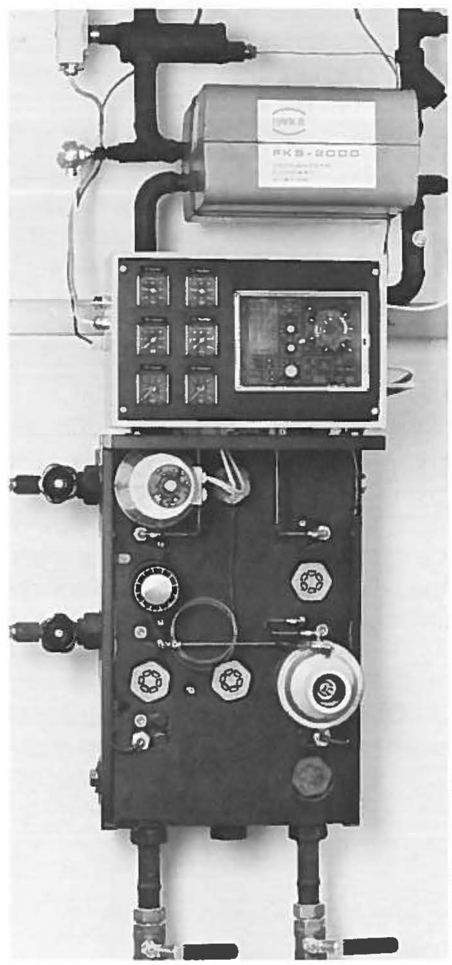


Photo: IWK Regler und Kompensatoren GmbH

*Compact district heating transfer substations save both space and money. They can be fitted with all necessary devices required for heat transfer.*

reduce costs for both the utility company and the consumer.

### The Expansion Joint Advantage

In district heating lines, through which water flows at different temperatures, thermal expansion occurs. This expansion is taken up by bellows expansion joints. Highly specialized knowledge and long experience are required to manufacture and install such joints. IWK has been producing bellows expansion joints for district heating lines and other applications for six decades. In addition to the well-known basic types—axial, tied, and hinged expansion joints, IWK also produces many custom-made designs for special applications, with nominal diameters ranging from 6 to over 15,000 mm.

A customary method of taking up thermal expansion in district heating lines is by means of three-pin U-loop systems (Fig. 8). With a new, special hinged expansion joint with several bellows, IWK has doubled the angular rotation. By using this type of joint in the central section of the three-hinged U-loop system, the projection (L1) can be halved.

A new generation of axial expansion joints of the 307/232 type, intended primarily for district heating networks, offers advantages not only in terms of space-saving; thanks to the novel guide design (Fig. 9), lift is limited on both sides and the expansion joint thus protected against torsion. Compression and tensile forces are transferred direct. The joint, which is protected by a fully closed casing, is available in nominal diameters of DN 200 to DN 1,000, and for pressures of between PN 10 and PN 40. Lines can be pressure-tested without determining the anchor points beforehand.

With pressure-balanced expansion joints, there is static equilibrium of forces under operating and testing pressure. This relieves the anchors and thus considerably reduces construction costs. For this reason, a series of pressure-balanced expansion joints has been added to the IWK range. These joints have a very high resistance to kinking. They can be prestressed as required on site by applying pressure to the compensating bellows.

### Building on the Success

As a result of modern engineering methods, connection of individual residences and apartment houses to district heating networks is becoming an increasingly attractive possibility. Conversion costs are low. Existing central heating systems, piping, and radiators can be retained. Since boilers and tanks are no longer required, space is saved, especially in new buildings. If compact substations are installed, even less space is required. The district heating consumer has no maintenance costs to bear; and approximately one-half of the heating costs are fixed costs which can be calculated down to the last cent.

**FIGURE 9**

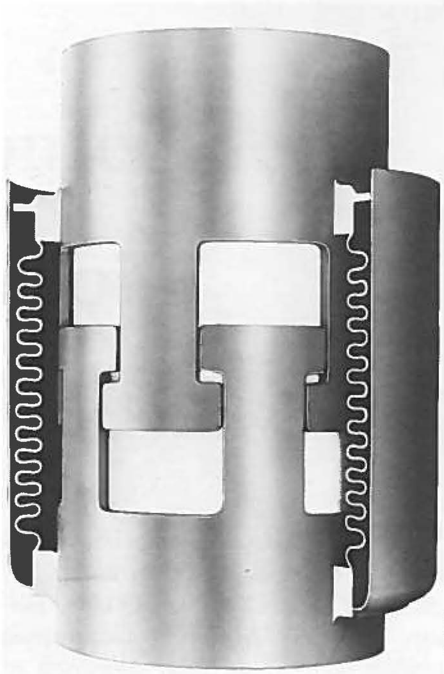
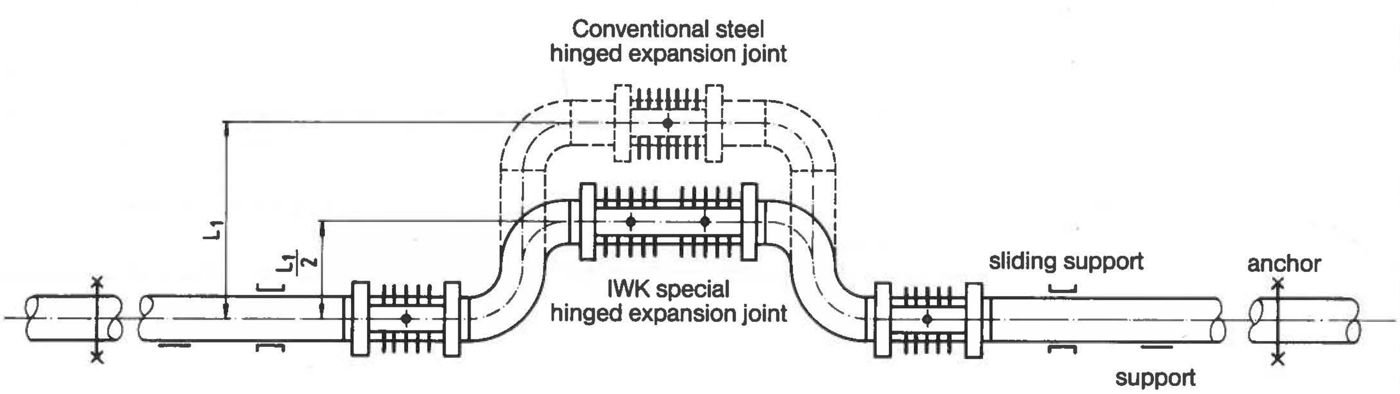


Photo: IWK Regler und Kompensatoren GmbH

*Axial expansion joint with protection against torsion and limited lift on both sides.*

In Karlsruhe, the US Military Administration recognized the advantages of district heating. Now, it is once again holding talks with the city authorities and the municipal district heating company: the subject this time is the Gerszewski Barracks in north Karlsruhe. If an agreement is reached the heat requirement of the municipal district heating network will increase by some 15 MW, i.e., 5% of the total connected load.




Drawing: IWK Regler und Kompensatoren GmbH

*Three-hinge U-loop systems represent a customary method of taking up thermal expansion district heating lines. A new, special hinged expansion joint has been developed with which angular rotation is doubled and the projection (L1) thus halved.*