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duction; not subject to stress corrosion or metal fatigue; are self-restraining; rich results in low anchor forces, reduced pipe stress and fewer guides and hter anchors. Economic advantages are gained through these features plus the duced design and installation time, and the fact that vast amounts of movement n be accommodated through the use of only two joints (Fig. 11).

A COMPARISON OF HEAT DISTRIBUTION SYSTEMS IN THE U.S.A. AND THE WORLD

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The use of underground distribution systems is constantly growing, and may be rectly related to the increasing number of and need for large multiple building omplexes, in private, public, military projects, urban renewal, and satellite city rograms (Figs. 1, 2, and 3). Population trends will accelerate the need for these rograms, and the central plant and distribution system concept offers several ortant advantages.

1. Usually lower initial cost.

Fig. 1—Aerial view of district heating and cooling system.
2. Higher operating efficiencies through application of more efficient boiler and fuel firing equipment, controls, accessories, fuels, and air pollution control than would be economically practical in much smaller individual plants.

3. Centralized maintenance, with fewer and better trained maintenance personnel.

There are a number of types of underground distribution systems in general use today.

1. Concrete tunnels. Properly constructed walk-in tunnels have no particular disadvantage, except extremely high initial cost and in some cases space limitations. The cost disadvantage may be offset where requirements exist for large diameter multiple pipe installations.

2. Tile systems, utilizing mortar joints. Relatively low cost, but not completely watertight, and fragile.

3. Ducts of precast or poured-in-place concrete. These ducts are not completely watertight, so that pitch towards low points, adequate inspection points, drains carefully designed for site conditions, and ventilation are most important, and joint construction is critical.

4. Asbestos cement. Inert materials, not subject to exterior corrosion but somewhat fragile, and difficult to maintain watertightness. Unless specially treated or lined, asbestos cement is a pervious material. Also, there is some evidence to substantiate that soils of an aerated or acid nature have an enormous aggressive effect on this material.

5. Poured-in-place insulations. Under certain conditions subject to cracking and deformation when subjected to a wide range of temperature change. Generally not considered suitable for wet ground conditions. Low cost.

6. Pipe insulated with closed cell insulation, usually polyurethane, and jacketed...
with PVC. Not air testable, drainable, or dryable; most commonly used in low-temperature applications; has definite temperature limitations.

7. Properly coated steel, or uncoated cast iron conduit. The steel system is the most widely used and accepted. Generally, the steel conduit with welded joints offers, at the present time, the most economical and by far the most suitable combination of initial cost and long service life under a reasonably wide range of conditions, such as wet, corrosive, or unstable soil. Also, the steel conduit system lends itself well to controlled factory fabrication and testing techniques, and can usually be built to exact job dimensions and requirements (Figs. 4 and 5). Field work and installation time are thus minimized.

The industry engaged in the manufacture of underground heat distribution systems has grown somewhat haphazardly, partially, perhaps, because of the relatively few manufacturers engaged, and until recently, the lack of competitive stimulus. Underground distribution systems had been a source of difficulty for many years, due to several factors.

1. Inadequate technical knowledge of the processes of heat and moisture transfer under typical underground conditions.

2. Inadequate understanding of inter-related effects of the many materials and
Fig. 4—Prefabricated conduit system part drawing layout.

Fig. 5—Setting conduit with elbow fabricated on straight section.
construction components of a system that have a bearing on the successful performance of the system.

3. The multiplicity of different materials and constructions offered for such systems, all of which have some of the desired characteristics.


In the general recommendations contained in these reports, emphasis is laid upon the importance of selecting qualified design engineers and installing contractors, and upon close inspection and supervision by the system's manufacturer during critical periods of the installation. Usually, the manufacturer is required to submit written reports to the user's representative, or contracting officer.

Water is, of course, the major adverse factor encountered in underground systems. The initial step in determining the type of system that must be used is the determination of job or site conditions. Some basic criteria were developed for testing and classifying sites. Any site where water or the water table is expected to be above the bottom of the system at any time is to be considered a Class “A” site. Therefore, a system installed in a Class “A” site must possess certain characteristics (Fig. 6) as determined by specific test procedures.

1. Watertightness.
2. An unobstructed air passage proved suitable for drying out the insulation within a reasonable period of time. This is generally defined as a minimum of one-in. annular air space between the outer surface of the insulation or bare pipe, and the inner casing wall.
3. Designed and constructed to permit air pressure testing of the system at any time.
4. System must be capable of being drained in place, if it becomes wet.
5. The interior pipe insulation must be capable of withstanding boiling, such as would take place in the event of inner pipe failure.

The above standards are based upon the assumption that all systems may eventually become wet, through improper handling during installation, subsequent inner pipe or casing failure, flooded trenches, etc.

Insulation is installed around the heat pipe to limit heat loss, and since the presence of water greatly reduces the insulating characteristics, raising operating costs, and in extreme cases eliminating heat delivery, a system that cannot be dried without damage is useless. Also, the corrosive effect of water on the heat carrying pipe is an important consideration.

In establishing a reasonable drying time, it must be considered that many users cannot be without heat for extended periods, and the system would not be out of service during the drying period, since as the system is drying, heat can be de-
livered in reduced quantities, which would increase gradually during the drying period. It must be also noted that before the drying process can begin, the water must be drained from the system, while the system is in place.

Minimum standards must, of course, be set for insulation thickness, which determine system efficiency. Further desired characteristics of insulation are that it should be a non-conductor of electricity; after being subject to boiling and drying tests it should not exhibit physical damage or thermal loss beyond specified limitations; and it should be of premolded or poured-type which can be dried readily, has known density and thickness, and will not settle or sag away from the pipe if properly applied. Further, it should be vermin proof and chemically and dimensionally stable at the operating temperature of the pipe. The most recent government specifications have standardized on calcium silicate as best meeting the above requirements. It is suggested that on steam systems, condensate return lines installed in the same conduit with steam lines need not be insulated.

Bearing in mind that water is the main enemy, the importance of an effective waterproof coating on all metal surfaces in contact with the earth must be emphasized. Certain criteria were developed to set minimum standards of acceptability for these coatings. The minimum performance recommended, and later adopted by many government agencies, including all the military services, is that no waterproofing material should be used that has a permeance of more than .25 perm. (Value in perms equals the number of grains of moisture that would pass through one sq ft of the materials in one hour under a vapor pressure differential of one in. of mercury.) The material used must not, of course, soften or flow at operating temperatures. (Later criteria specified a temperature limit for “sag” at 220 °F as a skin temperature that might be obtained if the inner pipe failed in a properly vented system.) Heat cycling tests were devised as additional
criteria. The 1959 report No. 30R suggested that coal tars are the most effective of the bituminous materials, since they have long been established as having almost zero permeability, lower moisture absorption characteristics, and superior resistance to chemical and bacteriological attack than other bituminous coatings. (Most recent government coating criteria includes chemical immersion tests.) However, other bituminous materials are still used, since they are able to meet the minimum established standards mentioned above. It should be mentioned here that these federal standards are intended to establish a minimum level of acceptability. Specifying engineers may, unless prohibited by law or special regulations, specify materials, or a level of performance that exceeds a minimum standard.

In steam distribution systems it is recommended that ferrous condensate lines be placed in a separate conduit, except, perhaps in the case of small branch lines. This is true because the ferrous condensate line would be the first to fail, and thus would jeopardize the entire system. Ferrous condensate lines should always be extra heavy. Where a non-ferrous condensate line is used in the same conduit with a steam line, dielectric construction should be used; no contact of dissimilar metals should be permitted (Fig. 7).

In high-temperature water systems the question of single or multiple pipe installations can be decided on the basis of economics. It is generally economical to combine smaller diameter pipes in a single conduit, and to install larger diameter pipes in separate conduits.

It was recommended that wherever possible, expansion loops or offsets should be used in underground piping systems (Figs. 8 and 9) to provide for pipe movement due to expansion resulting from temperature change. It was recommended by the government criteria that expansion joints should only be used where necessary, as determined by layout and space requirements. The conduit manufacturer can design the conduit expansion loop to be compatible with the rest of the conduit system, and assume responsibility for its function.

Proper handling and installation procedures are most important. The following procedures were recommended.

1. Excavations should be kept free of water at all times.
2. Backfill, after all tests have been completed, should be clean earth and fine gravel or suitable excavated material, properly tamped.
3. Proper care should be taken in storing and handling material at the job to prevent component or coating damage, and to keep the insulation dry. Internal casing coatings are required, to protect against corrosion prior to installation.
4. Proper test procedures should include an air pressure test of the casing, hydrostatic test of the service piping, and a Holiday spark test to locate any defects in the exterior casing coating.

These same reports developed some criteria for Class B systems for job sites where some water would occasionally be present for infiltration into the system, even though the surrounding ground would be unsaturated. Some thought is now being given to development of criteria which would, in suitable environmental conditions, permit use of other types of systems that do not meet present criteria.

The introduction of the above mentioned reports, plus increased competitive stimulus, has led to improved technology, product improvements, and wider use of these systems, due partly to increased confidence in their performance. Among some of the recent changes in criteria or product development may be mentioned the following:

1. Use of heavier gauge casings and better coating materials. Galvanizing used to be considered a basic requirement for steel casings. However, the chief value of galvanizing is to function as a sacrificial anode, in effect an uncon-
controlled form of cathodic protection, and when an overlying dielectric coating is applied, the ability of the galvanizing to perform this function is defeated. Further, most of the zinc must be burned away before the field joint can be welded. Borrowing a technology originally developed in the gas transmission industry, where the older galvanizing technique is now almost unheard of, increasing acceptance is being given to the idea that the best way to combat corrosion is to use heavier gauges of steel, further protected by the more efficient coatings now available, such as the coal tar enamels referred to above. The gas transmission industry generally used multiple layers of plasticized coal tar enamel, fiberglass mesh for structural reinforcement, and coal tar saturated asbestos felt overwrap to obtain maximum protection. This system is available to the more progressive conduit manufacturers. Heavier steel casings possess a further advantage over light gauge
Fig. 8—Two-piece expansion loop.

Fig. 9—Two-piece expansion loop in trench, open field joints.
galvanized or black steel; welding collars are not required, and where unexpected field conditions are encountered, they can be cut, trimmed, or otherwise modified and welded at the site. In addition, where highly corrosive or dissimilar soil conditions, stray currents or other interference effects are encountered, a properly designed cathodic protection system can offer a relatively inexpensive form of additional protection, or insurance, can be designed for a specific life expectancy, and enable the level of protection to be checked by measuring the pipe to soil potential.

2. Newer types of spacer supports for the inner pipes have been developed, that provide insulation of the pipe continuously through the spacer, with no heat gap, offer dielectric isolation of the service pipe, and are contained within the annular air space, so the system can be efficiently drained and dried (Figs. 10 and 11).

3. A monitoring system has been developed for leak detection in underground conduit systems (Fig. 12). This is a system for pressuring the casing with nitrogen or other commercially available inert gas or air. A control system is installed to measure possible pressure changes and signal changes by means of an audio and visual alarm system; rise in pressure indicating a service pipe leak, or a drop in pressure indicating a casing leak. An alternate version of this system can provide an air compressor to introduce air into the casing at a slightly greater head than the surrounding ground water, should a leak occur, thus preventing water seepage. Also, the system should be equipped with a rupture disc and pressure limit control to close a valve or stop a pump, should the inner service pipe fail, thus preventing rupturing of system segments. System segments can be monitored separately by connecting them back to a conveniently located annunciator panel, through direct buried nylon tubing. Pressurizing the casing with nitrogen offers certain other advantages. Since it is an inert gas, the “K” value of the service pipe insulation goes down, reducing thermal losses. Due to its low moisture content, uninsulated return lines will not “sweat.”

4. Prefabricated steel utility manholes, which are completely factory fabricated and tested under controlled conditions, including all internal piping, valves, fittings, specialties, and insulation, with conduit stubouts welded through the manhole wall, and completely corrosion protected. These units are air tight and pressure testable, which concrete manholes normally are not, and considerably reduce field installation time and labor (Figs. 13 and 14).

5. Fiberglass reinforced plastic casings are now available for use in underground pipe conduit systems. These systems, where joints can be maintained watertight, have the obvious advantages of inert materials, being impervious to corrosive soil conditions. However, at the present time, the higher initial costs of this type of system will tend to limit its use to special applications or conditions.

6. In recent years some use has been made of epoxy coatings applied to steel conduit casings. However, no uniform criteria have been established by which these types of coatings can be evaluated. Previously testing procedures developed in National Academy of Sciences reports No. 39 and 39R were developed primarily for bituminous coatings and some thought is now being given by the Federal Construction Council to developing criteria for the epoxy coatings. However, again, the higher cost of these coatings tend to limit their use. Also, the newer development of fiberglass reinforced plastic casings may entirely replace the epoxy coated steel conduit for the special application situations.
SINGLE-PIPE NON-OVAL SUPPORT

SINGLE-PIPE OVAL SUPPORT

Fig. 10—Single pipe spacer support.
MULTI-PIPE NON-OVAL SUPPORT

MULTI-PIPE OVAL SUPPORT

Fig. 11—Multi-pipe spacer support.
FIG. 12—Monitoring system.
Fig. 13—Conduit run into prefabricated manhole.

Fig. 14—Interior of prefabricated manhole.
7. An expansion device has been developed which permits small branch take-offs to serviced buildings, which in many cases can eliminate need for anchoring at each takeoff, and reduce the cost of installing expansion loops in the main distribution lines (Fig. 15).

8. Some further indications were developed in National Academy of Sciences report No. 47S that cellular glass systems could operate satisfactorily in dry climates where ground at the system level is never saturated and, of course, where temperature limitations are properly considered.

9. Some limited evidence was also considered in report No. 47S that direct burial of uninsulated condensate lines is feasible, and economical. For this application, some installations of fiberglass reinforced plastic pipe are being made, and results being evaluated.

In recent years there has been a trend towards district and group heating schemes in Europe and the United Kingdom. Some of the reasons for this trend may be of interest, since they may be indicative of or point towards trends which are developing or will develop in the United States.

In England, in 1964, a study group was set up by the Heating and Ventilating Research Association on behalf of the Design & Heating Study Group (solid fuel) and a publication issued entitled “District Heating, A Survey of Practice in Europe and America,” and published by the National Coal Board.

For purposes of the study, district heating was defined as a system where heat is generated and distributed by an independent firm or authority, and sold to users. Group heating was defined as a system where heat is generated and distributed to a system of buildings under the same control as the heat generating authority.

At the time of the study, outside of Russia and the United Kingdom, 140 large district heating systems plus several hundred group or cooperative systems existed. In Denmark, for example, in 1964 about 14 per cent of space heating requirements were met by communal plants, which was expected to increase to 26 per
cent by 1970, and to 37 per cent by 1973. In the United Kingdom at the time there were about 10–12 group heating schemes serving residential areas, and a large number of plants supplying industrial, institutional and service buildings. In West Germany heat supplied through district systems went up from five trillion Btu in 1950 to 35 trillion in 1960.

The report outlined some of the interrelated factors affecting the choice of district heating:

1. Area or load density.
2. Economic factors in individual countries or areas such as availability or proximity of fuel sources and type.
3. Emphasis on minimizing air pollution. This was particularly true in West Germany, where clean air legislation encouraged district schemes.
4. Transportation costs incurred in delivering fuel to and removing ash from individual households.
5. Government subsidies or protection for the coal industry, which favored the adoption of large group and district schemes fired by solid fuel.

In Western European countries, the trend at the time of the 1964 study indicated an emergence of specialist firms of contractors that designed, installed, operated, and maintained smaller group heating schemes. Typical types of systems in use were:

1. Ducts of precast or poured-in-place concrete, or brick, with pipe insulation of aerated concrete, preformed sectional or loose fill. Most common of these was the precast concrete duct, in six ft sections. Provisions were usually made to drain the duct, usually tile below the trench or duct, covered with a few inches of crushed rock, and a small drain trough or channel cut into the base of the duct.
2. A trend was noted by the study group to the use of preinsulated and sealed pipe, and had proved satisfactory thus far. No uniform standard or criteria was being applied to casings, coatings, annular air space, insulation, or field joint methods.

No one insulating material had found universal preference. Problems with aerated concrete cracking under expansion and contraction with mains were noted. Loose fill insulation had not proved satisfactory. Granular materials, such as vermiculite had a tendency to settle and compact, and required a long drying time after wetting. Insulating hydrocarbons (not requiring ducts) were heat cured to provide consolidated, sintered, and loose zones, but doubts were expressed in the report as to proper formation of the three zones, and failures attributed to imperfect curing and sintering.

In the United Kingdom district heating is a fairly new concept, since central heating itself is recent for residences there. Originally the few systems that were built were in concrete or brick ducts, and some in cellular concrete. Considerable trouble was experienced with water entry into these systems. There is a considerable increase in numbers of systems taking place now, due mainly to the fact that the major oil companies and the National Coal Board have started up heat supply companies to supply fuel and operate boiler plants on behalf of clients. There is also presently, a greater increase in incorporating refuse incinerators as part of the total concept, and plans seem to be formulating for future new town developments on a total energy basis. The state-owned Gas Board is also entering this market, using natural gas fuel.

An American conduit manufacturer entered the English market several years ago through a licensee arrangement, followed a year later by another American manufacturer. Due partly to their efforts, and the history of bad experiences with other types of systems, the British Standards Institution published in 1969, British Standard 4508: Part 1: 1969, entitled "Specifications for Thermally Insulated
Underground Piping Systems," "Part 1. Steel Cased Systems with Air Gap." This publication points out that most sites in the United Kingdom are wet at some periods and establishes criteria in Class A (wet) sites. The same basic criteria was established for Class A sites that exist in the United States, pressure tight, testable, drainable, and dryable. In accordance with this standard, Class A systems may possess design characteristics similar to Class A systems in the United States, except that coal tar enamel coatings are mandatory, manholes must be prefabricated steel construction, coated the same as the conduit pressure tested and vented. Also, reference is made to an air or nitrogen monitoring system complete with controls, leak indicator, and gas supply as a refinement for optional consideration.

Two American conduit manufacturers are presently operating in the Common Market, giving impetus to the growth in use of preinsulated, prefabricated pipe conduit systems. In 1968 COSTIC (Committee of Science & Technique of the Industry of Heating, Ventilating and Air Conditioning) in Paris, France, completed a one-year accelerated corrosion test on sections of buried pipe conduit provided by an American manufacturer through its English licensee. Following the test the sections of conduit were re-excavated and examined. The report concluded that "the tests of the two PERMA-PIPE lengths have been carried out without incident, and no corrosion had been observed."

In April, 1970 a conference entitled the "First International District Heating Convention" was held in London, England, organized by the District Heating Association of England, the Heating Ventilating, and Air Conditioning Manufacturers Association of England, and the Institution of Heating and Ventilating Engineers of England. There were in attendance approximately 600 delegates from 27 countries. Papers were presented by representatives of 12 different countries. Some highlights follow.

At present there is a total heat value of 3.6 billion dollars per year controlled or otherwise delivered through district heating schemes throughout the world, at least half of which are in the U.S.S.R. It was the feeling at the convention that the market for district heating schemes is just beginning in most parts of the world, and that the implication of pollution problems in the industrial countries would serve to increase the pressure for these schemes.

District heating in Sweden is growing rapidly, exceeding forecast each year. They anticipate that an upper limit forecast for the future would be that 20–25 per cent of total heating requirements would be furnished through district heating schemes. Plants are built as heating plants (do not include turbine exhaust), and utilize insulated pipe lines laid in concrete ducts. At the present time in Stockholm, they have several separate heat distribution systems, and are considering a policy of linking these systems for flexibility of operation and standby.

In Denmark there are presently six combined power stations and heating plants, and in addition, some 450 heating-only plants. At present about 20 per cent of all heat used is furnished from district systems. Almost all new central systems to be built in the future will be in new housing areas, since most of the existing inner city areas are already equipped with district heating systems, for low rise housing as well as high rise buildings. They are also furnished the heat for domestic hot water, by including heat exchangers in each building. Average expenditure for central systems is in the range of $1,000 to $1,200 per dwelling, including total amortization of the central system and the main. At the present time approximately 30 per cent of all dwellings are heated by central plants, and it is anticipated that by 1975 this figure will rise to 40–45 per cent. Another influencing factor is the feeling that good heating prevents disease, so providing heat as a public utility will tend to increase public health. Distribution systems are mostly low-temperature hot water, many of which utilize polyurethane foam insulation with a PVC jacket.
In Italy the major reason for district heating is to minimize air pollution. Large district heating plants are accepted in northern Italy, but due to legal difficulties, it is not presently economical to combine them with power stations. Distribution systems were varied; concrete ducts, insulating hydrocarbons, foam glass buried in sand, and some asbestos cement systems are used.

In France, a large number of district heating systems are being built by private companies. Some of the distribution systems utilize concrete ducts drained to sewers, others are using low cost materials such as poured-in-place fill insulations, etc. Recent tests by COSTIC indicate a trend or desire to upgrade present standards.

In Germany, heat supply is undertaken in many areas by local city governments, particularly in center city areas for major communities. The city of Hamburg, for example, has one of the largest district heating systems in the world. Most heat distribution has been done with insulated piping in concrete ducts; some serious recent failures have been experienced with asbestos cement encased systems, powder infill and cellular concrete systems. Considerable success has been recently experienced with the steel encased air tight pressure testable systems. One major municipal system in the Dusseldorf area is utilizing a steel encased system with a vacuum permanently maintained in the casing annulus, which not only provides continuous monitoring of the casing integrity, but adds to the insulating value of the system.

In Hungary the pressure for district heating was motivated by a serious fuel shortage. For this reason they have been using power station turbine exhaust extensively for district heating schemes. Some natural gas resources have recently been discovered which might make turbine exhaust stations uneconomical. New high rise apartment developments are emerging which they feel will produce the high density patterns that will make district heating concepts increasingly economical.

Polish distribution schemes utilize prefabricated concrete ducts. They have experimentally used other types of piping systems such as powder infill insulated concrete, but have had no experience with steel encased systems.

In the Soviet Union all new industrial and residential combinations now being built are being heated from central systems. At the present time 40 per cent of the heating load is furnished through district systems. Construction of mains seems to be insulated piping in concrete ducts. All of the systems are hydraulically isolated, with a main circulating system, and separate circulating systems with separate pumps in each building. Some of the more complicated systems are equipped with automatic valve locks to cut off particular zones in the event of pressure loss due to leakage. They felt this was important as a fuel saving device.

In Japan the city environments are rapidly being polluted, and for largely this reason, district heating schemes started in 1960. A social and public policy has been adopted to minimize pollution through the use of district heating schemes. It is felt that in the future all city plans should provide for the distribution of heat as a public utility. They feel that the 1970's are a critical time for their cities, and district heating will develop rapidly. They are presently developing a computer program for a total energy analysis for city planning, to compute a district energy system, and use the program to determine the most economic form to distribute heat energy in different population density areas.

Canada has a number of district heating schemes, particularly in large cities. Toronto is at the present time considering extending their system to the central business district. They are developing a computerized mathematical air quality model to determine the impact of extending district heating schemes on air pollution in the city areas. There has been no substantial government pressure for district heating schemes for residential developments.
In his closing remarks at the 1970 convention, the chairman, Sir Derek Ezra, emphasized the importance of district heating, and indicated that much technical development was presently under way. He felt that planning of new cities would include district heating as a standard public utility, and that renewal of existing cities would provide for many extensive district heating projects. He indicated that Russia and Scandanavia have virtually completed the potential of district heating installations, that the United Kingdom had made a good beginning, and Japan was just commencing in this area. A second such conference is being planned, probably to take place in Copenhagen in 1972.

In industrialized areas of the world, in order to expedite the reduction of pollution emissions there has been a major shift towards more costly energy sources, particularly natural gas. The known reserves are not increasing at the same rate as increase in usage, nor are the known reserves as great as the known reserves of lower cost fuels. In the long range, it will be increasingly difficult to depend on natural gas fuel to control air pollution in urban areas. This is already happening in some areas of the U.S. One of the long term solutions is the utilization of other fuels in more complex central plants, associated with major district or group heating schemes.

District heating has been sometimes regarded as a source of problems to be avoided, or as a byproduct, (and perhaps necessary evil) of power generation. It appears that the time has come to look beyond the problems, towards solutions already developed and now developing, so that the economic and social benefits of district and group heating schemes may be developed to their fullest potential.

TWENTY-INCH ALIGNMENT GUIDE FAILURE AND IN-SERVICE REPAIR

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In 1966, a 20-in. steam transmission line was installed that would provide for increased system growth in the area west of the Schuylkill River. In addition, this line would form part of a loop integral with other transmission loops in the system. Studies indicated the most feasible scheme, from the economic standpoint, was a combination above and below grade line. The above-grade position was installed along the right of way of the Penn Central Railroad. Slip-type expansion joints with long traverses were used to minimize the number of structures along the railroad right of way. In 1500 ft of above grade line, a total of three enclosures were used; two to house expansion joints, and one for a drip point and flash tank. Due to the grades adjacent to the railroad and the curvature of the right of way, there were several directional changes requiring alignment guides. The design conditions for the line were 225 psig and 450 F.

This line had been in service for approximately three years when it became necessary to shut it down to make a connection to it. Prior to the proposed shutdown in the fall of 1969, while the above-grade alignment guides were being greased, it was noted that an alignment guide had failed. Fig. 1 shows the layout of the line in the section in which the alignment guide had failed. This guide was located approximately 340 ft from the anchor, with a change in direction in the horizontal plane of 10 deg 43 ft, resulting in an unusually large lateral thrust as well as a long traverse. Manufacturers’ standard alignment guides consisting of