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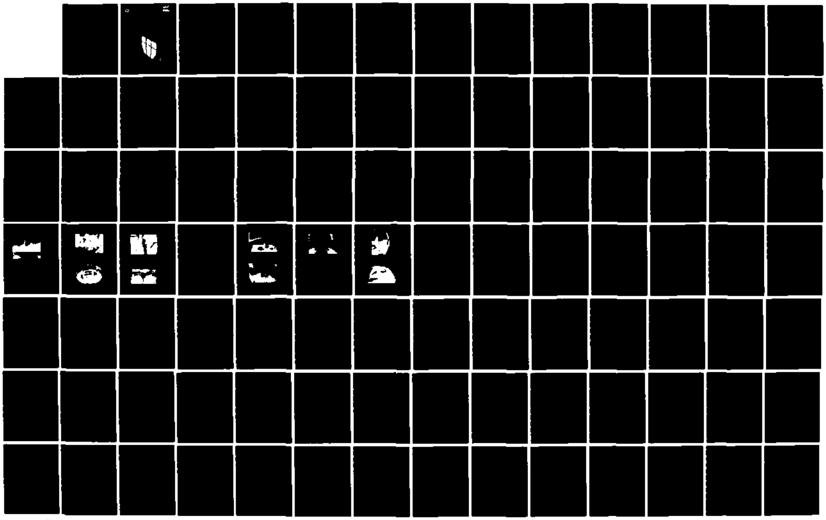

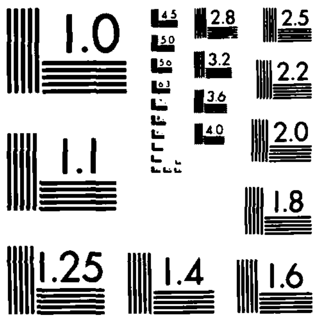
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US Army Corps of Engineers
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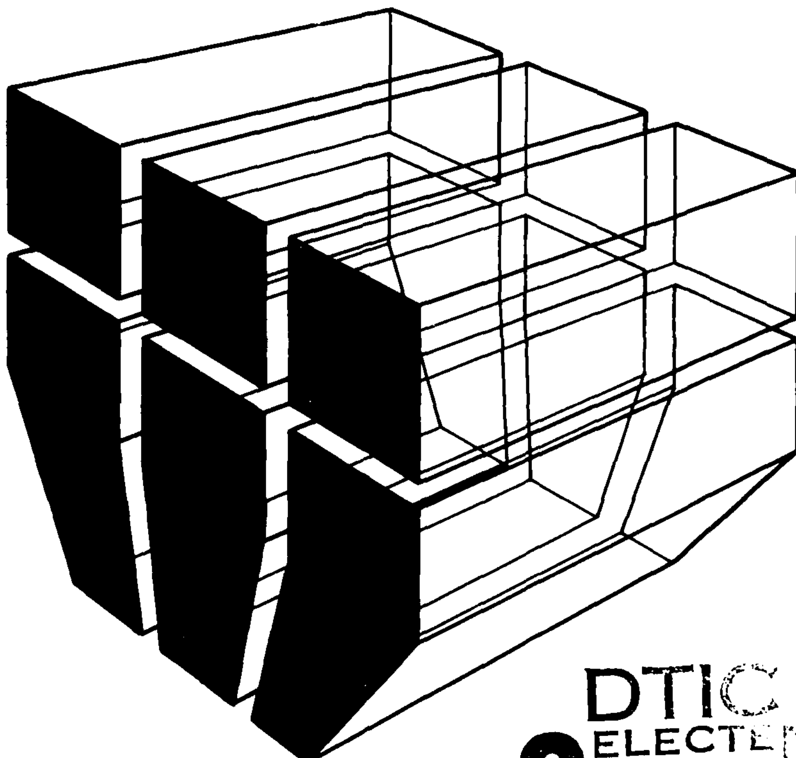
AD-A145 181

TECHNICAL REPORT M-347
June 1984

INVESTIGATION OF TRI-SERVICE HEAT DISTRIBUTION SYSTEMS



by
Ellen G. Segan
Ching-Ping Chen

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The objective of this research was to evaluate the physical condition of prefabricated steel conduit underground heat distribution systems built in accordance with the Tri-Service Specifications for Underground Heat Distribution Systems (Army, Navy, and Air Force documents CE-301.21, TS-P28g, and Air Force Pamphlet No. 88-007-1, respectively) and to recommend changes to new specifications as necessary. Other types of heat distribution systems were also inspected where convenient.

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The objectives were met by conducting field surveys at eight Department of Defense (DOD) installations; a total of 66 sites were inspected. The results were compiled and the performance of systems as a function of site classification was assessed.

The results of this investigation were:

1. Specific problems with prefabricated steel conduit systems were observed and discussed.

2. Problems with the prefabricated steel conduit systems were attributed to deficiencies in design, construction, and maintenance of the systems.

3. Deficiencies in following established guidance contributed to problems with conduit systems.

4. A need exists for additional guidance for the design, construction, and maintenance of conduit systems.

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EXECUTIVE SUMMARY

The energy selection criteria in Army Regulation (AR) 420-49 have resulted in increased use of large, coal-fired central heating plants which require efficient and reliable heat distribution systems to meet the energy needs of military installations. The Tri-Service Specifications for Underground Heat Distribution Systems* were developed in the 1960s to establish criteria for the design, construction, operation and maintenance of these systems. In 1976, Federal Construction Guide Specification (FCGS) 15705 was published, but has only been used for construction since about 1981. FCGS 15705 establishes criteria based on the systems approach of procuring underground heat distribution systems and establishes relaxed site classification criteria; however, the basic technical concepts have remained essentially the same since the development of the Tri-Service Specifications.

The objective of this investigation was to evaluate the physical condition of systems built according to the Tri-Service Specifications and to recommend changes in the present guidance as required. The decision to perform this study was prompted by allegations from field installations of high energy losses in their systems and the fact that no investigation to date has addressed the performance of underground heat distribution systems built according to the Tri-Service Specifications.

The objectives were met by conducting field surveys at eight Department of Defense (DOD) installations where system users stated that they had problems associated with prefabricated conduit systems. It was initially intended that only the prefabricated conduit systems that complied with the Tri-Service Specifications be inspected. However, the investigation was expanded to include other systems, because their proximity to the prefabricated conduit systems allowed useful information to be gathered. The other systems included above-ground insulating concrete, shallow concrete trench, buried concrete trench, insulating powders coated with stearic acid, clay tile, and fiberglass reinforced plastic (FRP) systems. A total of 66 sites at the eight installations were surveyed and analyzed.

The results of this investigation were:

1. Specific problems with prefabricated steel conduit systems were observed and discussed.

2. Problems with the prefabricated steel conduit systems were attributed to deficiencies in design, construction, and maintenance of the systems.

3. Deficiencies in following established guidance contributed to problems with conduit systems.

4. A need exists for additional guidance for the design, construction, and maintenance of conduit systems.

*These specifications for the Army, Navy, and Air Force are CE-301.21, TS-P28g, and Air Force Pamphlet No. 88-007-1, respectively.

The major findings are summarized below.

Evaluation of System Performance

Type A prefabricated conduit systems were found to be satisfactory on Class A sites when installed in strict compliance with criteria. About half the systems observed had significant problems which could be attributed to design or construction deficiencies. The problems were compounded by failures to perform preventive maintenance and to take corrective actions when problems occurred.

Both Type A and Type B systems were found to perform satisfactorily on Class B sites. Three Type B shallow concrete trench systems were found to be performing satisfactorily on those sites classified as Class A by CE-301.21 and as Class B by FCGS 15705. Data were insufficient to assess the performance of shallow concrete trenches on sites which would be classified as Class A according to both FCGS 15705 and CE-301.21.

Insulating powder and insulating concrete systems, which are not approved for Class A or Class B sites, did not appear to perform well. Although only a few systems were observed, the results suggested use of these systems should be avoided.

Half-round clay tile systems, which were not approved for Class A or B sites, were in relatively good condition. Since, repair of problems in these systems is difficult, the use of these systems should be avoided.

Above-ground systems, which are approved for any type of site, performed well. These systems offer many advantages, but their interference with aesthetics and with mobility of personnel and equipment often precludes their use. It was recommended that system designs that do not interfere with aesthetics be investigated.

Site Classification System

The results of the field inspection indicated that many sites classified as Class A experience high water infrequently or not at all. Classification of these sites as Class A may be too stringent if concrete trench systems can perform satisfactorily. It was recommended that the site classification criteria be reviewed and that the feasibility be investigated of allowing concrete trench systems on sites which are submersed infrequently.

Prefabricated Conduit System Components

The conclusions and recommendations for the components of the prefabricated steel conduit systems are compiled according to the severity of deficiencies observed and the causes of the deficiencies.

The Tri-Service guidance was found to be valid and there were no recommendations for changes in the areas of:

1. Conduit exterior coating

2. Conduit interior

3. Pipe supports

4. Calcium silicate insulation

5. Supply pipe exterior

6. Waterproofing of manhole walls.

The Tri-Service Specifications were found to be valid in the following areas, but failure to follow established guidance was causing serious problems in carrying out the intent of the specifications:

1. Backfill

2. Sump pumps

3. Manhole drainage

4. Manhole ventilation

5. Conduit drains

. Conduit vents

7. Leak detection and identification of type of leak.

The Tri-Service Specifications were found to be deficient in that they did not provide for:

1. Required cathodic protection for soils with resistivity below 10,000 ohm/cm^3

2. Insulation of condensate return lines.

3. Preventive maintenance of systems

4. The effects of system shutdown on performance

5. Leak detection and location

6. System slope

7. Manhole design accessibility and safety

8. Leaking valves in manholes

9. Separation of chilled-water PVC piping and heat distribution piping

10. Coating of conduit end plates

11. Sealing of manhole walls around conduit entry to manholes

12. Selection of tie-strap materials.

In some cases, it appeared that further investigation of problems and possible solutions was necessary, while in others, the problems have at least partially been rectified in FCGS 15705 or suggested changes to existing criteria were made.

FOREWORD

This investigation was performed for the Directorate of Engineering and Construction, Office of the Chief of Engineers (OCE), under Project 4A162781AT45, "Energy and Energy Conservation"; Task B, "Installation Energy Conservation Strategy"; Work Unit 011, "Modernization of Existing Underground Heat Distribution Systems." The applicable STOG is 81-8:2. The OCE Technical Monitor was Dale Otterness, DAEN-ECE-E.

The investigation was performed by the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (CERL).

This report is a result of the cooperative efforts of team members from the Army, Navy, Air Force, and private industry. The study team consisted of the following individuals:

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Dr. Robert Quattrone is Chief of CERL-EM. COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Department of Defense (DOD) installations are major users of underground heat distribution systems. DOD maintains about 6000 miles of steam and high-temperature hot-water lines, most of which are underground. The 1984 cost of rebuilding this system would be several billion dollars.

The energy selection criteria in Army Regulation (AR) 420-49[1] have encouraged increased use of coal-fired central plants at Army installations. Centralized heating plants offer military facilities many advantages over decentralized facilities, including the capability to burn coal cleanly and efficiently, and the ability to remain self-sufficient in the event of energy shortages. Such plants require efficient and reliable heat distribution systems. However, because of their size, these systems have an inherent potential for large energy losses, and even a small decrease in overall efficiency can waste large amounts of energy and natural resources.

In the late 1940s and early 1950s, installation of underground heat distribution systems increased, and the unacceptable failure rates of the systems began to attract the attention of construction agencies. In 1967, the Tri-Service guide specifications for underground heat distribution systems were developed on the basis of a series of studies conducted by a National Academy of Sciences (NAS) Federal Construction Council (FCC) Task Force. These Tri-Service Specifications (U.S. Army Corps of Engineers Guide Specification CE-301.21,[2] U.S. Navy Facilities Engineering Command Specification TS-P28g, and Air Force Pamphlet No. 88-007-1) were mandatory for their respective services, both for new construction and for maintaining existing systems. The specifications establish criteria for design, construction, maintenance, and operation of underground heat distribution systems. They also establish requirements for evaluating the systems based on site classification criteria: Class A sites are defined as those having severe water table problems, and Class B sites are defined as those having no problems with soil moisture or water tables.

Although it appeared that the failure rate of underground heat distribution systems had been significantly reduced by use of the Tri-Service Specifications, no surveys had been conducted to determine whether the criteria were effective and whether the recommended guidance was being followed.

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[1] Heating, Energy Selection and Fuel Storage, Distribution, and Dispensing Systems, AR 420-49 (Department of the Army, 18 November 1976).
[2] Heat Distribution Systems Outside of Buildings, CE-301.21 (U.S. Army Corps of Engineers, April 1967).

In 1969, the FCC concluded that the criteria used to develop the Tri-Service Specifications needed further updating because they appeared to be too inflexible and prevented the development of new types of systems. This led to the development of Federal Construction Guide Specification (FCGS) 15705 in 1976.[3] The requirements for Class A systems remained basically the same, but the site classification system was revised to introduce a systems approach for design and construction.

Industry resistance and unfamiliarity with new test procedures precluded the implementation of FCGS 15705 for more than 5 years. As a result, the systems approach and new site classification process have only been used since 1981. It appears that it will take several years to assess the performance of systems installed under FCGS 15705.

In 1981, the present study was undertaken by the U.S. Army Construction Engineering Research Laboratory (CERL) at OCE's request to:

1. Evaluate the effectiveness of the 1967 Tri-Service Specifications in providing efficient and economical heat distribution systems

2. Assess whether the Tri-Service Specifications are being followed and whether nonconformance is leading to premature failures

3. Recommend changes in the guidance where necessary.

Objective

The objectives of this investigation were to:

1. Inspect and evaluate the physical condition and general performance of heat distribution systems installed in compliance with the 1964 Military Tri-Service Publication and the 1967 Tri-Service Specifications, as well as other types of systems

2. Recommend changes to the criteria and new guide specifications based on the results of the field inspections.

Approach

Seven types of underground heat distribution systems were inspected at eight DOD facilities by teams made up of Army, Navy, and Air Force personnel. The facilities were selected on the basis of problems with prefabricated steel conduit systems. Although only the study of prefabricated steel conduit systems was originally planned, the study was later expanded to other types of systems where convenient, because of the usefulness of the information they could provide.

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[3] Underground Heat Distribution Systems (Prefabricated or Pre-Engineered Type), Federal Construction Guide Specification 15705 (NAS-FCC, April 1976).

The teams inspected 66 sites, evaluating them in terms of site classification, soil types, and system component condition. The teams evaluated system condition based on energy efficiency, appraised component conditions, and recommended corrective actions where problems were observed.

The data were compiled and used to evaluate both the overall performance of the systems investigated and the effectiveness of the Tri-Service Specifications.

Mode of Technology Transfer

It is recommended that the information in this report be used to revise Federal Construction Guide Specification FCGS 15705, Underground Heat Distribution Systems (Prefabricated or Pre-engineered Type).

2 DEVELOPMENT OF CRITERIA FOR UNDERGROUND HEAT DISTRIBUTION SYSTEMS

Underground heat distribution systems have been used since 200 BC, when the Romans used fired-clay piping systems to distribute warm air from a central plant to outlying structures. In the 1910s and 1920s, there was an increase in the use of underground systems for distributing steam, but this use declined in the 1930s and 1940s. In the late 1940s and early 1950s, the Federal Government began large construction programs to build airfields, hospitals, research facilities, and office buildings. This construction was spread over large areas and increased the number of underground heat distribution systems. Central plant systems were chosen because they were more economical than boilers in individual buildings.[4]

However, during the 1940s and 1950s, as more underground heat distribution systems were being installed, their failure rates began to attract the attention of construction agencies. In the early 1950s, Congressional budget hearings on military construction projects focused their attention on these problems. Congress then mandated OCE with investigating the underground systems and recommending ways to reduce the large repair costs. OCE's preliminary investigation showed that:

1. There were no government, industry, or technical standards regarding heat distribution systems.

2. Although many companies manufactured and installed these systems, there was no technical association that would speak for the group as a whole.

3. Other government agencies, state institutions, and private users were having similar problems with repairing and replacing heat distribution systems.

4. No overall evaluations or studies of these systems had been made.

Because of this lack of information, OCE recommended a state-of-the-art study to develop technical criteria and guide specifications that would insure the improved performance of heat distribution systems. The Building Research Advisory Board (BRAB) Task Group of the FCC of the NAS was convened to carry out this recommendation. The task group encouraged participation of industry and other governmental agencies in the study.

The first BRAB-FCC report was issued in 1957.[5] This report compiled data from a survey of universities, private companies, and government agencies which produced and distributed steam and hot water for heating purposes. Respondents provided information on 11 different types of systems and their performance under varying soil conditions.

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[4] F. A. Govan, "Purpose of Criteria for Underground Heat Distribution," Proceedings of a Symposium on Underground Heat Distribution Systems, BRAB-FCC Symposium/Workshop No. 3 (NAS, BRAB-FCC, 1966), pp 1-3.

[5] Underground Heat Distribution Systems, Technical Report No. 30 (NAS, BRAB-FCC, 1957).

The task group determined that the major problem was an almost complete lack of design standards for underground heat distribution systems. Other deficient areas included:

1. None of the conventional insulating materials had all the characteristics required for underground applications.

2. Information about the behavior of waterproofing and insulating materials at the temperatures encountered in underground heat distribution systems was inadequate.

3. Data regarding soil moisture conditions around heat distribution systems were inadequate.

4. Installation procedures and lack of adequate inspection often contributed to system failures.

From 1958 to 1966, the task force prepared eight reports and revisions covering: detailed field inspections of 132 sites; meetings with industry representatives; evaluation of input from design engineers and maintenance and operating personnel; presentations by soils engineers, corrosion experts, and materials specialists; support by the National Bureau of Standards in preparing test programs; evaluation of data from field offices, design agencies, and users; and proceedings of a symposium on underground heat distribution.[6]

The task force found that the underground conduit systems failed mainly because of the deleterious effects of water on the system and its components. Susceptible parts of the system were exposed to water because of improper system design, materials, construction, inspection, and maintenance. Field inspections showed a strong correlation between wet and moist ground conditions and system failure rates. The task force proposed criteria for designing, constructing, and maintaining underground heat distribution systems which addressed the problems of water intrusion. The recommendations were not binding on government agencies, but were generally accepted as a basis for preparing individual guide specifications and criteria.

For military construction, DOD directed that a Tri-Service (Army, Navy, Air Force) Committee be formed to prepare design specifications and criteria for building underground heat distribution systems. The committee used the

[6] Underground Heat Distribution Systems (Revised and Updated to 1959), Techical Report No. 30R (NAS, BRAB-FCC, 1959); Evaluation of Components for Underground Heat Distribution Systems, Technical Report No. 39 (NAS, BRAB-FCC, 1960); Underground Insulated Piping Systems (Excluding Walk-through Tunnels), Technical Report No. 27 (NAS, BRAB-FCC, 1963); Field Investigations of Underground Heat Distribution Systems, Technical Report No. 47 (NAS, BRAB-FCC, 1963); Underground Heat Distribution Systems (Second Revision), Techical Report No. 30R-64 (NAS, BRAB-FCC, 1964); Evaluation of Components for Underground Heat Distribution Systems, Technical Report No. 39-64 (NAS, BRAB-FCC, 1964); Supplementary Field Investigation of Underground Heat Distribution Systems, Technical Report No. 47S (NAS, BRAB-FCC, 1966); Proceedings of a Symposium on Underground Heat Distribution Systems, BRAB-FCC Symposium/Workshop Report No. 3 (NAS, BRAB-FCC, 1966).

findings and recommendations of the BRAB-FCC Task Force to develop the Military Tri-Service Publication Procedures for Establishing Acceptability of Underground Heat Distribution Systems, and the Tri-Service Guide Specifications for underground heat distribution systems. The Tri-Service Guide Specification documents (U.S. Army Corps of Engineers Guide Specification CE-301.21,* U.S. Navy Facilities Engineering Command Specification TS-P28g, and Air Force Pamphlet No. 88-007-1) are identical except for paragraph numbering and internal administrative references. Use of the guide specifications and their notes was mandatory for the respective services, both for new construction and for maintaining existing systems.

The Tri-Service Committee established two sets of criteria for underground heat distribution systems: one for systems in wet conditions (Class A), and one for systems in dry conditions (Class B). The committee adopted the policy of using a qualified products list, which identified products that had successfully passed certain tests and were approved by the committee. With the cooperation of the National Bureau of Standards, detailed test procedures were produced for Type A and Type B systems. Manufacturers could have their products tested by an independent laboratory. Upon approval by the committee, the manufacturers were given a letter of acceptability, which made the manufacturer's brochure an integral part of the contract documents. The guide specification to which the letter of acceptability applied was broad in nature; it included prefabricated conduits and above-ground systems for Class A sites and concrete trenches for Class B sites. The Tri-Service Guide Specifications addressed site classification, soil corrosivity, materials and system watertightness, and system design, construction, and inspection. Appendix A summarizes the major provisions of the Tri-Service Specifications, including the site classification system.

Since the military was the greatest single user of heat distribution systems, the Tri-Service Specifications had a tremendous impact on the industry. Many manufacturers could not pass the tests or were unwilling to try, and eventually dropped out of the business. These included the manufacturers of insulating concrete, full- and half-round tiles, and loose-fill insulating powder systems. Only a few manufacturers received approval; these companies produced the pressure-testable conduit type which dominated the market thereafter.

In the years that followed the initial publication of the Tri-Service Guide Specifications, there were indications that the number of short-term requests for replacing underground heat distribution systems was declining. The performance of systems complying with the Tri-Service Guide Specifications

*CE-301.21 will be used in this report to reference the Tri-Service Guide Specifications (TS-P28g, AF Pamphlet No. 88-007-1, and CE-301.21) and Military Tri-Service Procedures for Establishing Acceptability of Underground Heat-Distribution Conduit Systems (1 July 1964).

was not investigated, and the extent to which the three services were complying with the existing guidance was not evaluated. According to an FCC report:

> In 1969, however, the FCC concluded that further updating of the criteria was in order because the criteria appeared to be too inflexible--requiring in some cases the installation of an unnecessarily expensive system and precluding in other cases the use of a system with essential special features--and were not applicable to several new promising system concepts. The FCC therefore requested its Standing Committee on Mechanical Engineering to review and revise, as appropriate, the underground heat distribution system criteria presented in FCC Technical Reports Nos. 30R-64 and 39-64.[7]

The review and revision of FCC Technical Reports Nos. 30R-64 and 39-64 resulted in the development of FCC Technical Report No. 66 in 1975. The report's recommendations include the use of a systems approach to design and construction and the expansion of the site classification system to four categories to allow for new concepts, with the requirements for Class A systems remaining essentially the same. The recommendations were incorporated into Federal Construction Guide Specification (FCGS) 15705 in 1976. Appendix A summarizes the major provisions of FCGS 15705 and its site classification system.

[7] Criteria for Underground Heat Distribution Systems, Technical Report No. 66 (NAS, BRAB-FCC, 1975).

3 GENERAL APPROACH AND METHODOLOGY

The investigation team selected the installations and specific sites to be included in the inspection. Data from the inspectors' observations were collected and evaluated. The investigation process can be categorized into three steps: (1) selection of location and site, (2) inspection, and (3) evaluation.

Selection of Location and Site

The eight installations studied were selected because of problems associated with prefabricated steel conduit systems, the type of heat distribution systems, and the height of the water table. Of these, the primary criterion was the existence of prefabricated steel conduit system problems. The specific inspection sites within each installation were selected by participating team members using information from maps of the heat distribution systems and suggestions of base personnel.

Inspection

Initial information and data were collected through interviews with installation personnel responsible for operating and maintaining the systems. The installation's maps of the heat distribution system and engineering drawings of the system were also studied.

The site inspections covered not only the specific site, but also adjacent manholes and/or system entries to buildings. Soil was excavated at each site to expose the conduit. An opening about 10 by 12 in. was cut in the conduit with an oxyacetylene torch to help evaluate the heat supply and/or the return lines; the lines were usually in operation. Table 1 lists the information gathered at each site and notes system-specific information. The format of Table 1 has been used to present the field investigation results given in Appendices B through I.

Evaluation of System Performance

The condition of the heat distribution system observed at each site was empirically evaluated based on the system's ability to distribute heat efficiently. Although thermal loss data is not available for many deficiencies, the effect of a particular problem on energy efficiency can be assessed. For example, the thermal conductivity of water is much greater than that of air or calcium silicate insulation; therefore, a flooded conduit or manhole would have a serious effect on a system's energy transmission efficiency.

The condition of a particular system was assessed by summarizing the results of the field investigations in tabular form, noting serious deficiencies in the system components. Systems were evaluated as efficient (A) [illegible]cient with minor problems (B), not efficient--repair (C), and not effi[illegible] replace (D), based on the extent to which the deficiencies observed aff[illegible]

Table 1

Data Gathered During Field Inspection of Underground Heat Distribution Systems*

1. Location

2. Date of Inspection

3. Date of System Installation

4. System Description and History

5. Excavation Characteristics
   a. Soil condition
   b. Evidence of heat loss
   c. Depth of burial
   d. Backfill

6. Adjacent Manhole or Building Entry
   a. Manhole condition
   b. System penetration

7. Conduit (C = prefabricated conduit system)
   a. Conduit temperature
   b. Conduit coating
   c. Exterior surface of conduit
   d. Interior surface of conduit
   e. Inside of exposed conduit
   f. Other features

   Tile (H = half-round clay tile system)
   a. Tile and concrete pads
   b. Waterproof joints
   c. Inside of exposed area
   d. Other features

   Trench (B = buried concrete trench system; S = shallow surface trench system)
   a. Concrete portion
   b. Joint area
   c. Inside of exposed area
   d. Other features

8. Thermal Insulation
   a. Insulation material
   b. Tie-strap
   c. Surface temperature of insulation

9. Heat-Carrying Pipe
   a. Supply pipe exterior
   b. Return pipe exterior

*The results of the site surveys are presented in Appendices B through I.

the system's efficiency. Table 2 lists the components used to evaluate system performance.

Systems were classified as "efficient" when there were no significant problems that affected heat transmission or system accessibility. Systems were classified as "efficient with minor problems" when problems did not have a large effect on efficiency. For example, efficient systems with minor problems include those with such deficiencies as:

1. Lack of easy access to the manhole components

2. Small amounts of water in the manhole

3. Manhole ventilation problems

4. Corrosion of manhole components

5. Degradation of conduit coating

6. Minor exterior corrosion of the conduit which will not prevent the system from performing efficiently.

Once the deficiencies become serious enough to hinder efficiency, the system must be replaced or repaired. Systems were classified as "not efficient--repair" if they could be returned almost to their original thermal efficiency through cost-effective actions. Examples of repairable problems are:

1. Loss in efficiency because of water entering the system from flooded manholes due to corroded end plates, missing drain plugs, leaking valves, or open vent

2. Flooding of manholes

3. Isolated leaks in the conduit or carrier lines

4. Isolated weld failures in heat-carrying pipes

5. Accidental puncture or weld opening in casing

6. Damage of the insulation within a manhole.

Systems were classified as "not efficient--replace" when the cost of repair would exceed the cost of replacement. Some examples of such a system include those with:

1. General corrosion of the heat-carrying pipe

2. Heavy corrosion and deterioration of the conduit throughout the system

3. Disintegration of large amounts of insulation within the conduit, causing large energy losses.

Table 2

Component Deficiencies Used To Evaluate the Overall Condition of Heat Distribution Systems

Manhole Deficiencies	Conduit Deficiencies	Insulation System Deficiencies	Carrier Pipe Deficiencies
Inaccessibility	Coating failure	Wet insulation	Carrier pipe corrosion
Water in manhole	Exterior corrosion	Insulation not intact	
Conduit flooding	Interior corrosion		
Inadequate ventilation			
Severe corrosion of components			

4 DESCRIPTION OF HEAT DISTRIBUTION SYSTEMS INVESTIGATED

Table 3 shows the heat distribution systems investigated and some of their identifying features.

Prefabricated Steel Conduit System

The steel conduit system consists of prefabricated sections of heat-carrying pipe, insulation, and conduit which are welded in the field. Figure 1 is a diagram of a typical cross section and field joint of the steel conduit system. Each prefabricated section has a steel conduit (smooth or corrugated) containing a heat-carrying pipe. The carrier pipe is usually insulated with preformed calcium silicate or mineral wool insulation. The preformed insulation is secured with stainless steel tie straps, and the supports for the pipe are either steel or insulating block. An annular air space (1 in. minimum) is required between the insulation's surface and the interior of the conduit. The exterior of the conduit is coated with mastic waterproofing material. The waterproofing is a sandwich construction consisting of a steel/mastic/fiberglass/mastic/roofing paper (or felt) arrangement. At the entry of the system to a manhole or building, an end plate is welded onto the conduit to prevent entry of water. Vent and drain openings are provided in the conduit at system entries to manholes and buildings.

Prefabricated steel conduit systems fall into two categories: those with separate conduits for supply and return lines (C-1), and those with the supply and return lines contained in the same conduit (C-2).

Prefabricated steel conduit systems of the C-1 type are allowed on Class A sites as defined in CE-301.21 (1967). The C-2 type of system is not allowed because relatively frequent failures of condensate return lines have resulted in premature failure of both the steam-carrying lines that are contained in the same conduit and of the conduit.

Above-Ground System

The above-ground system (A) consists of a heat distribution system elevated above the ground on supports. Pipes are insulated with calcium silicate and covered with aluminum jackets. This system is allowed on any type of site. Its advantages include:

1. Low initial cost
2. Easy maintenance
3. Long life.

Disadvantages include:

1. Obstruction of the natural beauty of an installation

Table 3

Heat Distribution Systems Investigated

Major System	Subsystem	Name of Major System	Subsystem Description
C		Prefabricated Steel Conduit	
	C-1		Separate conduit for supply and return lines
	C-2		Supply and return lines in one conduit
A		Above Ground	
B		Buried Concrete Trench	
	B-S		Removable top slab
	B-C		Top slab cast in place
F		Fiberglass Reinforced Plastic (FRP)	
	F-C		FRP conduit with steel carrier pipes
	C1-FR		FRP condensate return line (high-temperature line is made of conventional prefabricated steel conduit construction).
H		Half-Round Clay Tile System	
P		Insulating Powder	
S		Shallow Concrete Surface Trench	
	S-U		Piping supported by U-bolts
	S-R		Piping supported by steel roller or guide on trench floor
Z		Insulating Concrete	
M		Combination of Walk-Through Tunnel and Conduit System	

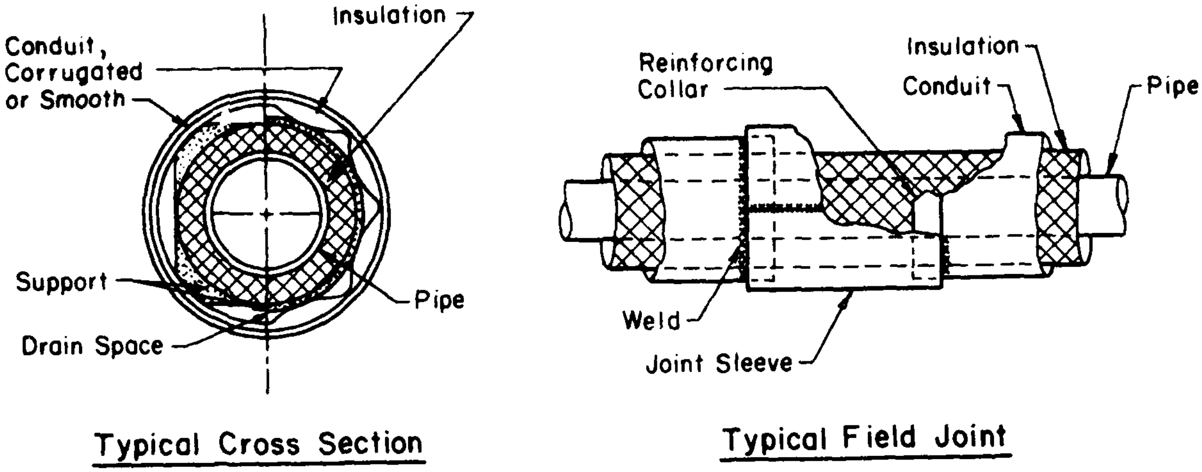

Figure 1. The prefabricated steel conduit system.

2. Restriction of mobility of personnel and equipment on the installation

3. Susceptibility to damage by high winds, cold weather, or atmospheric corrosion

4. Vulnerability to sabotage from the air and ground.

Insulating Powder System

The insulating powder system (P) uses the insulating and hydrophobic properties of insulating powders (usually calcium carbonate) whose individual particles are coated with stearic acid to insulate and protect the pipes. The thermal conductivity of the coated powders is about twice that of conventional calcium silicate insulation. Even though the initial cost of this system is low, it is not allowed for new construction, because it has not performed satisfactorily over long periods of time due to the chemical reaction of the insulating powder with its environment at elevated temperatures.

Shallow Concrete Surface Trench System

Shallow concrete surface trench systems have carrier and return lines and associated insulation placed into a concrete trench with removable concrete top slabs. The two types of trench systems observed were those with the piping supported by U-bolts (S-U) and those with piping resting on steel rollers or guides supported by the trench floors (S-R). Figures 2 and 3 show the S-U and S-R systems, respectively. Neoprene, polyurethane, or cement mortar is used as waterproofing material between the top and side slabs. The top slab can be used as a sidewalk and lifted off for repair operations.

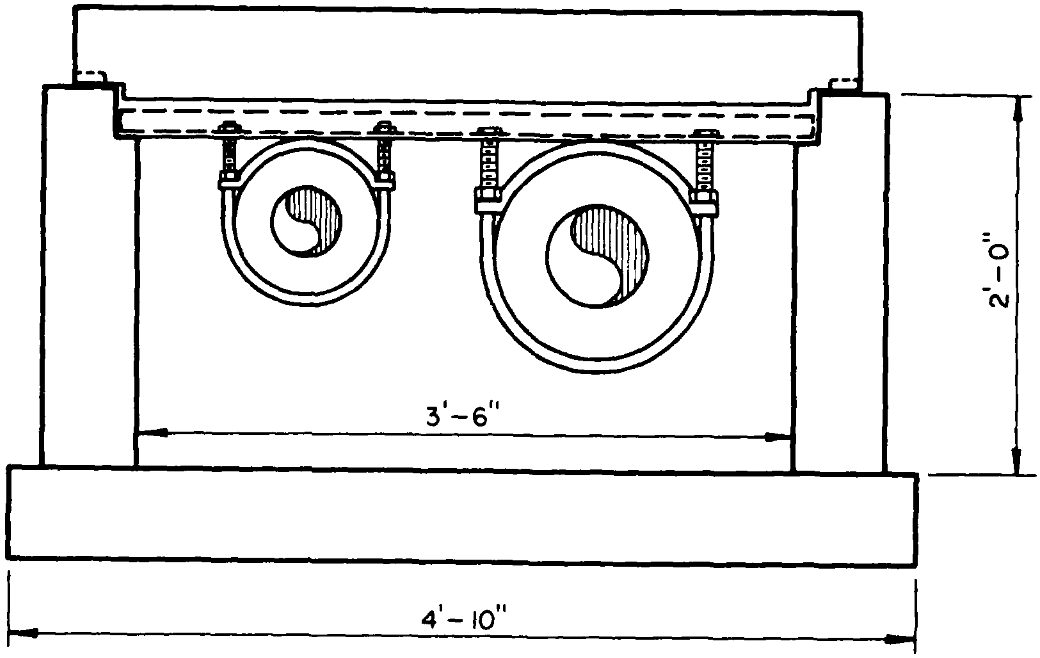

Figure 2. The shallow concrete surface trench (S-U) system, pipes supported by U-bolts.

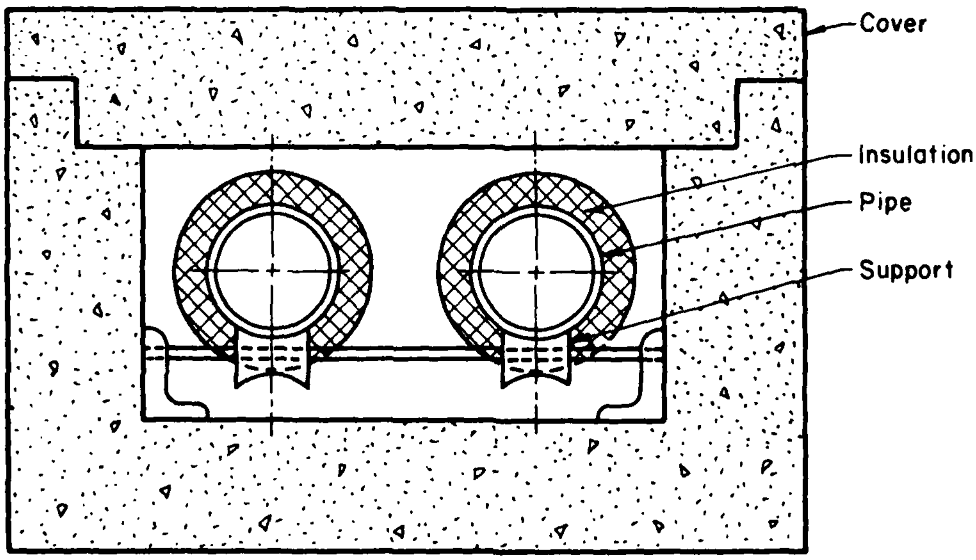

Figure 3. The shallow concrete trench (S-R) system, pipes supported on rollers or guides.

The shallow trench, which is approved for Class B sites, is not addressed in CE-301.21. However, as the criteria for Class B sites have been revised, recent guidance (FCGS 15705) has allowed for installation of shallow trenches on sites with higher water tables. (Appendix A describes the site classification systems of CE-301.21 and FCGS 15705.)

Some advantages of this system are:

1. Deep excavations are normally not required

2. Maintenance and repair of lines are simplified because leaks are easy to find

3. The system can be serviced with equipment and supplies available at the installation.

Disadvantages of the shallow trench system include:

1. Water can permeate through concrete

2. There are many joints which must be aligned and sealed

3. The system can interfere with the aesthetics of an area

4. The system depends on proper trench slope and manhole drainage to prevent accumulation of water along heat distribution lines.

Buried Concrete Trench System

The buried concrete trench system is similar to the surface concrete trench system except that it is entirely buried. Figure 4 shows a diagram of the system. Two types of buried concrete trench systems having different top slab construction were investigated. One system (B-S) had a removable top slab, and the other (B-C) was a monolith with the top slab cast in place.

The buried concrete trench is approved as a Class B system. It has the advantage over the shallow surface trench of not interfering with aesthetics; however, its repairability is seriously hampered by the excavation needed to reach the heat-carrying lines.

Fiberglass Reinforced Plastic (FRP) System

The FRP conduit system is similar to the steel conduit system (Figure 1) except that some of its components are made of FRP. For example, these systems use FRP as a conduit material, with the steel carrier and return lines arranged in common or separate conduits (F-C); CE-301.21 and FCGS 15705 prohibit placement of steam and condensate return lines in a common conduit.

The FRP condensate return system uses conventional steel conduit steam lines and FRP condensate return lines which may be buried directly (C-FR). FRP conduit systems were not included in the 1967 specification (CE-301.21), but one system is now approved for Class A sites.

The use of plastic instead of metal has the obvious advantage of avoiding corrosion. However, field-joining of FRP parts is complicated by the need for clean surfaces and the occasional requirement of auxiliary heat. These systems can be easily damaged in service by high temperatures or live steam and can be degraded by the environment.

Half-Round Clay Tile System

Figure 5 is a diagram of the half-round clay tile system (H), in which the half-round clay tile is laid on top of a concrete slab. The system is installed by pouring a continuous slab of concrete for a base, mounting the pipes on rollers and anchors supported by the base, and sealing the half-round bell and the spigot type of clay tile section to the base. The cavity between the pipe and the clay tile is filled with spun glass or mineral wool insulation. Each tile is installed in this manner. Repair is difficult, but can be done by local workers with readily available materials. This system was not included in the 1967 specification (CE-301.21) and is not used for new construction.

Insulating Concrete System

Figure 6 is a diagram of the insulating concrete system (Z), a lightweight insulation made of portland cement and vermiculite or perlite powder. The insulating concrete is mixed in the field and poured around the pipes. The system is waterproofed with about a 0.25-in. layer of bituminous material and can be strengthened with steel wire mesh beneath the bituminous coating.

The insulating concrete system is considered unacceptable for military construction. Field inspections in the early 1960s showed that it suffers from an extremely high failure rate. Many design variations were attempted by manufacturers at that time, but none were found to be effective. The major disadvantage of this system is that it cannot be kept dry in the field; the dryness of the system depends on the dryness of the membrane. Furthermore, excess water from the cement curing process can be entrapped if the system is sealed before curing is complete.

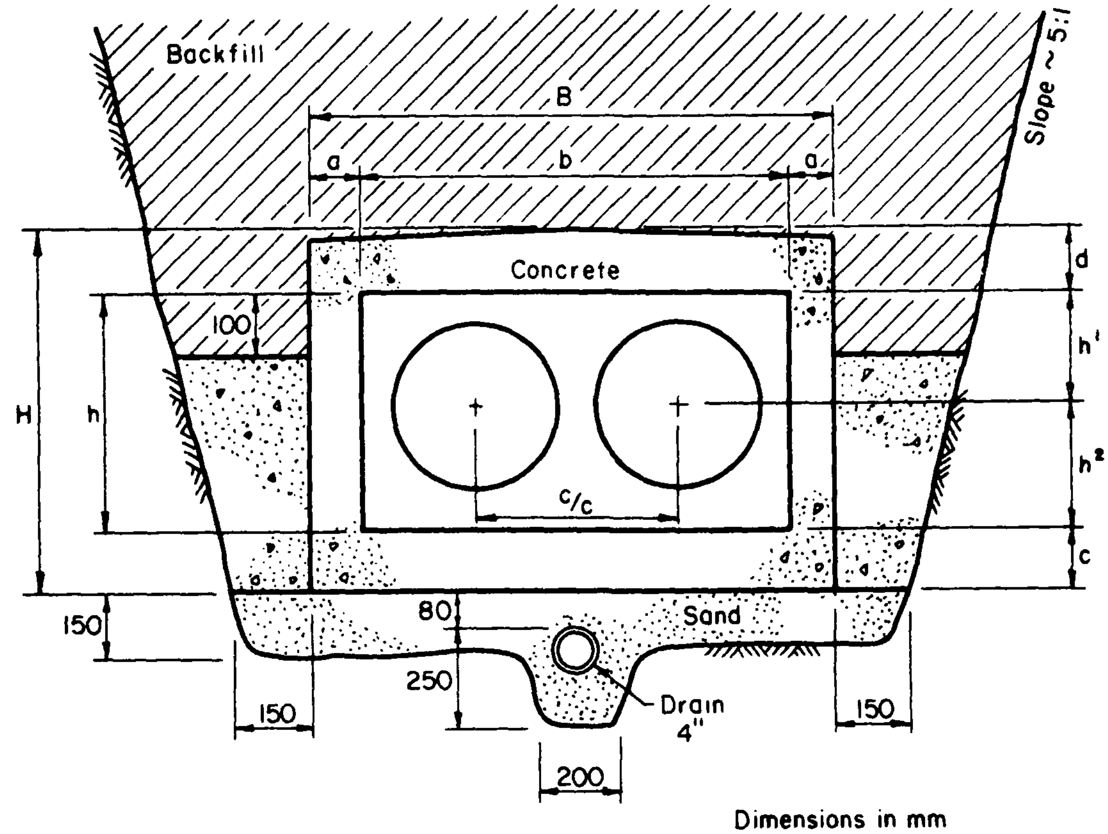

Figure 4. The buried concrete trench system.

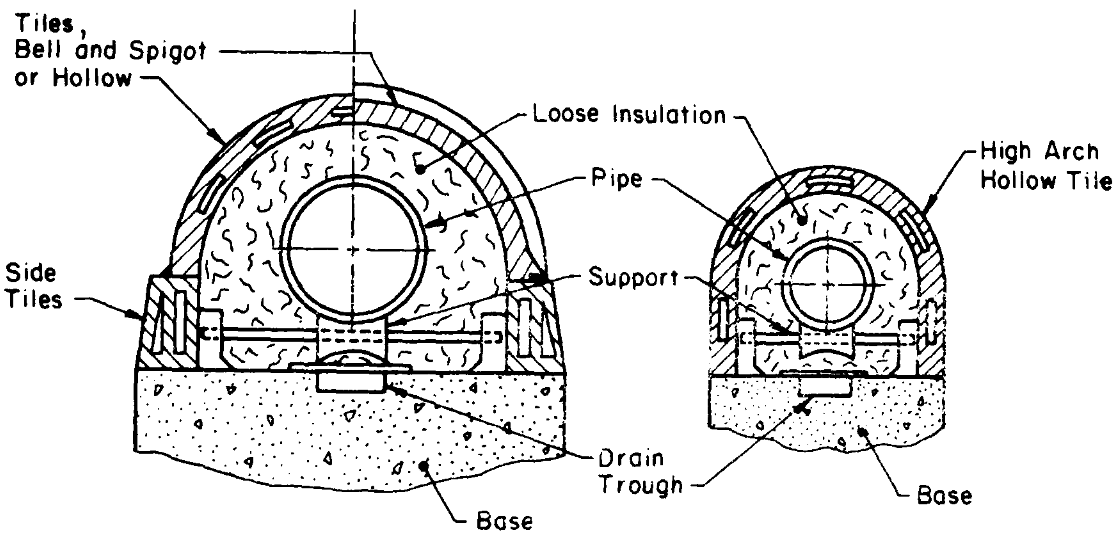

Figure 5. The half-round clay tile system.

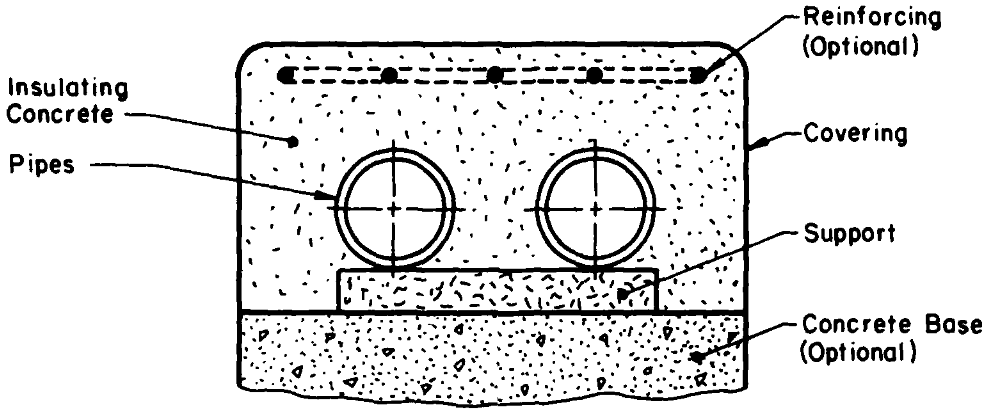

Figure 6. The insulating concrete system.

5 RESULTS AND DISCUSSION OF FIELD INVESTIGATIONS

Appendices B through I provide detailed results of the field investigations at the eight military installations. Appendix J presents the results of an additional survey conducted at Grand Forks AFB, ND, to determine water table levels, soil types, and soil resistivities.

Table 4 summarizes the results of the field investigations, showing the location, site number, system age, site classification (according to CE-301.21),* system type, component deficiencies, and condition of the system. The "X's" in the table indicate serious deficiencies observed in the components.

Site Classification System

There was evidence of manhole flooding at many Class A sites; this was not necessarily the result of a high water table. During the inspection, the water table was above the invert of the pipe at only two sites. Obviously, this is a seasonal effect, but in many cases, there was no evidence of any previous high water table. The current classification process can result in a Class A designation for sites which will experience high water infrequently or not at all. For example, some buried heat distribution systems may be submersed only briefly during spring and fall flooding, or once every 5 to 10 years when severe flooding occurs. Therefore, investigating the feasibility of allowing shallow trench systems on sites which are submersed infrequently appears to be appropriate.

Prefabricated Steel Conduit System

Prefabricated steel conduit systems were observed at the eight installations investigated. Table 5 summarizes problems observed with these systems by component and subcomponent.

The field investigation revealed that deficiencies in the underground heat distribution systems could be attributed to problems related to water intrusion, corrosion, and/or mechanical stress. In addition, many of the system operators were not familiar with the concept of pressure-testable, drainable, and dryable systems and the procedures required for proper maintenance and repair. Design and construction deficiencies also contributed to premature problems.

*Note that for the systems at Grand Forks AFB the site classifications are given according to both 1967 and 1976 guidance.

Table 4

Summary of the Findings of the Field Investigations

	System Age (yrs)	Site Classification	System Type	Manhole Deficiencies*: Inaccessibility	Water in Manhole	Conduit Flooding	Inadequate Ventilation	Severe Corrosion of Components	Casing Deficiencies*: Coating Failure	Exterior Corrosion	Interior Corrosion	Insulation System*: Wet Insulation	Not Intact	Carrier Pipe-Corrosion*	System Evaluation**
FORT KNOX, KENTUCKY (Location 1)															
Site 1	10	A	C-1	X	X		X	NA	X	X					B
2	6	A	C-2	X	X		X	X	X		X				C
3	41	B	B-S		X	NA	X	X	X	X		none present		X	D
4	13	A	C-1		X	X	X	X				X		X	C
5	12	A	C-1	NA	NA	NA	NA	NA							A
6	14	A	C-2		X	X	X	X	X	X	X	X	X	X	D
7	14	A	C-2		X	X		X							C
8	12	A	C-2		X	X	X								B
9	12	A	C-1	X	X	X	X	X	X		X		X	X	C/D
10	12	A	C-1		X	X	X	X	X				X		C/D
11	23	B	B-C		NA										A
FORT CAMPBELL, KENTUCKY (Location 2)															
Site 1	22	A	C-2	NA	NA	NA	NA	NA	X		X	X	X	X	D
2	4	A	C-1												A
3	12	A	H	NA	NA	NA	NA	NA				none present			C
4	31	A	B-S		X				X				X	X	D
5	26	A	H		X	NA			X	X		X	X	X	D
FORT BRAGG, NORTH CAROLINA (Location 3)															
Site 1	40	B	S-R		X	NA		X	X	X					B
2	40	B	S-R		X	NA		X	X	X					B
3	40	B	S-R		X	NA		X	X	X					B
4	40	B	S-R		X	NA		X	X	X					B
5	5	B	C-1		X	X					X				B
6	8	B	C-2	NA	NA	NA	NA	NA							A
7	8	B	C-2		X						X		X		B
8	26	B	H		X	NA								X	B
9	26	B	H		X	NA		X				X			C
10	15	B	C-2		X	X	X	X					X		C
11	12	B	C-2		X			X							B

Table 4 (Cont'd)

	System Age (yrs)	Site Classi-fication	System Type	Manhole Deficiencies*: Inaccess-ibility	Manhole Deficiencies*: Water in Manhole	Manhole Deficiencies*: Conduit Flooding	Manhole Deficiencies*: Inadequate Ventilation	Manhole Deficiencies*: Severe Corrosion of Components	Casing Deficiencies*: Coating Failure	Casing Deficiencies*: Exterior Corrosion	Casing Deficiencies*: Interior Corrosion	Insulation System*: Wet Insulation	Insulation System*: Not Intact	Carrier Pipe-Corrosion*	System Evalu-ation**
ANDREWS AFB, MARYLAND (Location 4)															
Site 1	9	A	C1-FR	X	X	X	X	X	X			X			C
2	9	A	C-1	X	X		X		X	X					B
3	11	A	C-1	X	X		X	X	X	X					C
NAVAL RESEARCH LAB, WASHINGTON, D.C. (Location 5)															
Site 1	5	B	C-1				X	X	X						B
2	11	B	C-2		X	X		X	X						B
3	9	B	C-1						X						B
4	9	B	C-1						X	X					B
5	not known	B	C-2		X		X			X					B
6	9	B	C-2		X		X		X		X				B
7	16	B	C-1		X	X			NA	NA	NA	NA	NA	NA	ID
8	30	B	S-U	NA	NA	NA	NA	NA	X	X		X	X	NA	D
9	30	B	S-U	NA	NA	NA	NA	NA	X	X	X	NA	NA	NA	D
10	30	B	S-U	NA	NA	NA	NA	NA	X		X	NA	NA	NA	ID
11	30	B	S-U	NA	NA	NA	NA	NA	X		X	NA	NA	NA	ID
FORT POLK, LEESVILLE, LOUISIANA (Locaton 6)															
Site 1	6	A	C-1	X	X	X		X	X			X	X	X	D
2	6	A	C-1	X	NA	NA	NA	NA	X			X			C
3	6	A	C-1	X	X	X			X	X		X		NA	C
4	6	A	C-1	X	X	X			X	X		X		X	D
5	6	A	C-1	X	X	X	X	NA	X	X		X			C
GRAND FORKS AFB, NORTH DAKOTA (Location 7)															
Site 1	24	A(A***)	C-1		X	X			X	X	X	X			C/D
2	26	A(A***)	Z	NA	NA	NA	NA	NA	X			X		X	D
3	4	A(A***)	B-S		X	NA			X						B
4A	10	A	P		X	X			X	X	X	X	X		D
4B	10	A	P		X	X			X	X	X	X	X		D
5	11	B	P	NA	NA	NA	NA	NA							B/C
6	3	A(A***)	S-U		X	NA							X		C
7	15	A(B***)	C-2		X	X	X			X		X		NA	C/D
8	6	A(B***)	C-2			X	X				X	X	X		D
9	9	A(B***)	F-C			X	X	X		X		X	X	NA	D
10A	5	A(B***)	S-U			NA								NA	A
10B	5	A(B***)	S-U			NA								NA	A

Table 4 (Cont'd)

	System Age (yrs)	Site Classi- fication	System Type	Manhole Deficiencies*: Inaccess- ibility	Water in Manhole	Conduit Flooding	Inadequate Ventilation	Severe Corrosion of Components	Casing Deficiencies*: Coating Failure	Exterior Corrosion	Interior Corrosion	Insulation System*: Wet Insulation	Not Intact	Carrier Pipe- Corrosion*	System Evalu- ation**
PENSACOLA NAVAL AIR STATION, FLORIDA (Location 8)															
Site 1	3	A	Cl-FR	X	X	X	X	X			X			X	C
2	5	A	Cl-FR	X	X		X	X			X				C
3	3	A	Cl-FR	X	X	X					X			X	C
4	7	A	Cl-FR	X	X	X					X			X	C
5	5	A	Cl-FR	NA	NA	NA	NA	NA	X	X	X	NA	NA	X	D
6	27	A	S-R		X		X	X				NA	NA	NA	B
7	not known	A	manhole		X		X	X	NA	NA	NA	NA	NA	NA	ID
8	8	A	Cl-FR		X		X	X	X		X		X	X	D

*Definitions:
NA = not applicable or information not available
X = serious deficiency is present

**System Evaluation Definitions:
A = efficient
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace
ID = insufficient data for a rating

***Soil classifications according to FCGS 15705 in August 1983 soil survey.

Table 5

Compilation of Problems Observed in Prefabicated Steel Conduit Systems

Component Investigated	Subcomponent Investigated	Problems Observed (Location Number - Site Number)
Excavation	Evidence of Heat Loss	Steaming at window (L1-2, L4-1, L6-3, L6-5, L7-1,7) Burned grass above conduit (L1-9, L6-5, L7-7) Hot ground (L3-6, 7, 11, L6-5) Snow melting above line (L5-1, L5-6)
	Backfill	No selected backfilling used; debris and junk materials found around conduit (L6-1,2) No selected backfilling (L1-1, L6-3,4,5)
	Slope of System	System improperly sloped (L6-1, 3, L8-8)
Manholes and System Entries to Buildings	Accessibility	No access ladder (L1-1, L8-1) Access ladder rungs severely corroded (L1-2) Manhole too hot to allow access (L1-9) Access hole too small (L4-1,2,3, L6-1) Piping interfered with access (L6-1,4) Manhole not accessible (L6-2,3,5) Poor ladder design (L8-3)
	Piping and components	Piping and components severely corroded (L1-2, 4,6,7,9, L3-10, L4-3, L5-1,2, L7-1, L8-1,8,9) Insulation missing (L1-2,7,9, L3-10, L4-1,3, L8-1,3) Leaking valve packing or joint (L3-7, L4-3, L5-1,6) Insulation deteriorated (L1-4,7, L7-1) Insulation damaged by people stepping on it (L6-3, L7-1)
	Drainage	Water present in manhole (L1-1,2,4,6,8, L3-7,10, L4-2,3, L5-2,5, L6-1,3,4,5, L7-1, L8-1,3) Water marks in manhole (L1-1,6,7,8,10, L3-5,10, L4-1, L7-7) No sump pump (L1-2,10, L3-11, L6-1,3,4, L8-1) Sump pump inoperative (L1-4, L3-5, L3-10) No drain (L1-9,10) Mud entry (L2-2, L6-1,4, L8-8) Improper drainage or plugged drain (L3-10, L7-1)

Table 5 (Cont'd)

Component Investigated	Subcomponent Investigated	Problems Observed (Location Number - Site Number)
	Ventilation	Ventilation not provided (L1-2,4,9,10, L5-1,5,6) Raised plate--water intrusion (L5-2,7) Not effective (L6-1,3, L7-1)
Condition of Adjacent Manhole or Entry	Manhole Structure	No or insufficient exterior waterproofing (L1-2,9) Open grating--water intrusion (L3-5,7,10,11) Top of manhole at grade level--water intrusion (L3-1, 10, Building L6-1) Cover not properly sealed (L4-2, L5-5) Cover too thin (L5-1, L6-3) Raised plate cover - water intrusion (L5-2,7) Improper waterproofing material (L1-6,10, L8-3) Top of manhole at grade - water intrusion (L6-1)
	Accessibility for Maintenance and Inspection	Not accessible due to flooding (L1-1,2,4,6,8, L3-7, 10, L4-2,3, L5-2,5, L6-1,3,4,5, L7-1, L8-1,2,3) Congestion at end plate area (L1-1, L6-1,3,4) Manhole too hot to allow access (L1-9)
Penetration of the Heat Distribution Systems Into Manholes and Building Entries	End Plate Coating	Coating deteriorated; end plate severely corroded (L1-6, L3-11, L6-1,3, L7-1,7, L8-1,3,6,8) Coating deteriorated; end plate severely corroded System allowing water intrusion (L1-2,4,6,9,10, L3-10) Minimal coating, end plate rusted (L3-5, L3-7, L4-1,3 L6-4) End plate in silt (L6-2)
	Conduit Drain Opening	Opening not located (L1-1, L3-10, L5-1,6, L6-2) Drain plug missing (L1-10, L3-7,11, L5-5,7, L6-3, L7-1, L8-1) Water flowed out of conduit of the plug (L4-1, L6-4) Rust in the bottom of the conduit (L5-2) Water dripping from opening (L5-7, L7-7) Plug rusted tight (L6-1, L8-8) Port never opened (L6-5) Port installed 90° off (L7-7) Opening too close to bottom of manhole (L8-1)
	Vent Pipe	Pipe connected to bottom of conduit (L1-1) No vent pipe (L1-4,6,8,10, L3-10, L5-1,6) Vent plugged with dirt (L4-1) Vent plugged; never opened (L6-5) Steaming vent pipe (L7-1,8) Pipe ended in manhole (L7-7, L8-1,8) Vent opening 90° off and plugged (L7-7)

Table 5 (Cont'd)

Component Investigated	Subcomponent Investigated	Problems Observed (Location Number - Site Number)
	Seal Around Conduit	Packing deteriorated (L1-2,9,10, L3-10, L7-7, L8-8) Asphalt dried and cracked (L3-5) Gap in wall at cement packing (L3-5) Rust at weld of conduit/manhole interface (L4-1) Link seal charred and cracked (L5-3,4)
	Thermal Expansion Loop Area	Improper slope (L6-1,3) Poor weld penetration and mismatch; crack at weld (L8-5)
	Conduit Coating	No fiberglass mesh; no felt in mastic coating (L1-1, L7-1) Coating chipped off (L1-1) Felt wrapping peeled off (L1-2) Coating not properly bonded to conduit (L1-6) Coating was brittle (L1-10) Blistered and cracked coating (L1-10) Coating too thin or mastic flow to pipe invert (L2-1, L3-5, L4-3, L5-3,4,6, L6-1,2,3, L6-4,5, L7-1,8, L8-5,8) No asphalt underneath mesh (L4-1, L5-2) No felt wrapping, only kraft paper (L4-2, L5-1) No felt (L4-3, L6-4) No fiberglass mesh (L5-3, L6-1) Mesh too coarse (L5-6) No evidence of galvanic coating (L7-1)
	Exterior Surface of Conduit	Surface severely corroded or pitted (L1-1, L4-2,3 L5-4, L7-7) Portions rusted/pitted (L1-6,9, L2-1, L4-1, L5-5, L8-1,3,5) Rust near field joint (L3-11, L7-1)
	Interior Surface of Conduit	Severe corrosion (L3-5, L8-1,3,4,5) Minor corrosion (L1-2,4,6,9, L3-6,11, L4-1, L5-1,2, L6-1,2,3,4,5, L7-7,8) Pitting corrosion (L1-6, L2-1, L3-7, L5-6, L6-1, L8-2,5,8)
	Conduit Interior	Wet mud at bottom of conduit (L1-3, L3-5, L7-1) Water in conduit (L1-5,6, L5-2,6, L6-1,2,3,4,5, L7-7,8, L8-3,8) Flaky insulation at bottom of conduit (L1-7, L4-1) Minor rust of pipe supports (L1-5,8) Pipe support rusted (L1-6, L6-2) Conduit near concrete support corroded (L2-2)

Table 5 (Cont'd)

Component Investigated	Subcomponent Investigated	Problems Observed (Location Number - Site Number)
Thermal Insulation System	Insulation	Saturated with water (L1-4, L1-6,9,10, L2-1, L4-1, L6-3,4,5, L7-7,8) In degraded condition (L1-6, L2-1, L6-1,3, L7-1, L7-7,8) Flaky (L1-7) Insulation blocks at the bottom of conduit (L1-9, L2-1, L5-4, L6-5, L8-8) Eroded pits on top or bottom (L3-7,10, L5-2, L6-1,2, L8-2) No insulation (L5-2) Damp insulation (L6-2) Signs of reaction between insulation and heat-carrying pipe (L8-1,2,3,4)
	Tie-Straps	Severe corrosion (L1-9, L6-2, L7-8) Minor corrosion (L6-1)
	Supply Pipe Exterior	Scattered minor corrosion (L1-2,6,9, L5-2, L6-2) Corrosion at insulation contact (L1-5) Light localized pitting (L1-6, L7-1, L8-8) Medium to heavy corrosion with some pits (L2-2, L6-1, L6-3, L6-5, L8-5) Severely corroded and pitted with signs of water intrusion (L8-1,3,4)
	Return Pipe Exterior	Severe scattered corrosion (L1-6) Internal corrosion (L2-1) Severe corrosion and pitting (L6-4) Minor deterioration of FRP line (L8-4) General corrosion (L8-5)

Leak Detection and Location

To a large extent, the repairability of prefabricated steel conduit systems depends on the ability of operating personnel to detect and locate leaks. Existing guidance addresses leak detection and identifying whether a leak is located in the conduit or carrier pipe. Leak detection is relatively simple if conduit vents are open, visible, and inspected periodically. Pressure tests of the conduit identify whether a leak is located in the conduit or in the carrier pipe.

Leak location has caused many problems for Facility Engineers. The probability of accurately locating leaks between manholes using remote techniques decreases with increasing depth of system burial; the probability of easily and accurately locating leaks in systems buried more than 15 ft deep approaches zero. In some cases, easily repairable systems were abandoned because of the inability to find leaks. Operating personnel were often not familiar with the uses and limitations of leak detection equipment. Thus, it appears that guidance for detecting and locating leaks in prefabricated conduit systems should be developed.

Excavation

Burned grass, hot ground, melted snow, or steaming ground were evidence of excessive heat loss at several sites (Table 5). Figure 7 shows an example of burned grass above a line. This was usually caused by flooded systems with ineffective insulation.

Poor backfilling techniques had been used at some sites (Table 5). Low-resistivity backfill can aggravate corrosion of heat distribution systems. Selection of appropriate backfill materials is critical in low-resistivity soil. Cathodic protection should be required when the resistivity of the adjacent soil or backfill is less than 10,000 ohm/cm^3, optional for soil resistivities between 10,000 and 30,000 ohm/cm^3 and not used for soil resistivities above 30,000 ohm/cm^3.

System Slope

Some systems were sloped improperly (Table 5), but this problem could not be easily detected during the field investigations; as a result, many cases of improper conduit slope may have gone undetected. CE-301.21 states that "All horizontal piping, unless otherwise indicated, should be pitched at a grade of not less than 1 in. in 40 ft in the direction of flow. All other piping, unless otherwise indicated, shall be pitched with a grade of not less than 1 in. in 40 ft toward the drain points." This results in a 0.21 percent grade for piping. Using a steeper grade could help in system drainage and reduce the chances that portions of the conduit are improperly sloped. The use of a steeper slope requires either deeper system burial or closer manhole spacing. It appears that the degree of slope required should be investigated.

Figure 7. Missing grass above line (L7-7).

Manholes and System Entries to Buildings

Many deficiencies in design, construction, and maintenance caused problems with manholes and system entries to manholes and buildings.

Accessibility. Poor manhole accessibility was frequently observed (Table 5). Lack of space and poor arrangement of components posed inspection problems, particularly for the prefabricated steel manholes (Figure 8). In some cases, improper installation of ladders made it difficult to even enter manholes (Figure 9). The deficiencies create both working and safety problems for maintenance personnel. Current guidance does not address specific designs for manholes in terms of how much space to allow for required maintenance, so there appears to be a need for it.

Piping and Components. Piping and components in manholes were often observed in poor condition (Table 5). Problems included corrosion, damaged or missing insulation, and leaking valves. Figure 10 shows rusted piping in a partially flooded manhole. Figure 11 shows seriously damaged insulation, piping, and end plates in a manhole which had been repeatedly flooded. Poor manhole design leads to insulation damage during maintenance operations, since maintenance personnel must often stand on the pipes to do their work. Inadequate drainage and ventilation of manholes causes corrosion of piping and components. Several leaking valve stems were observed; valves were often allowed

Figure 8. Entering a prefabricated manhole (L4-1).

Figure 9. Manhole entrance ladder (L8-3).

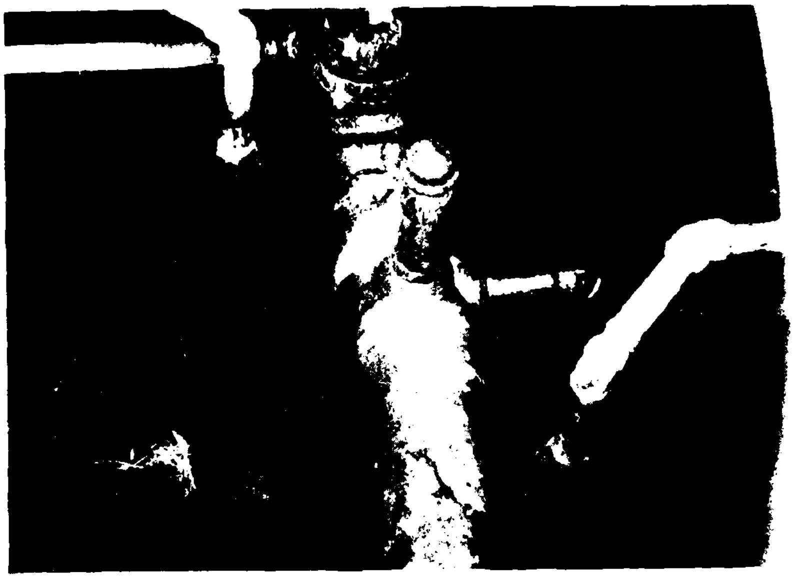

Figure 10. Severely corroded piping in manhole (L1-6).

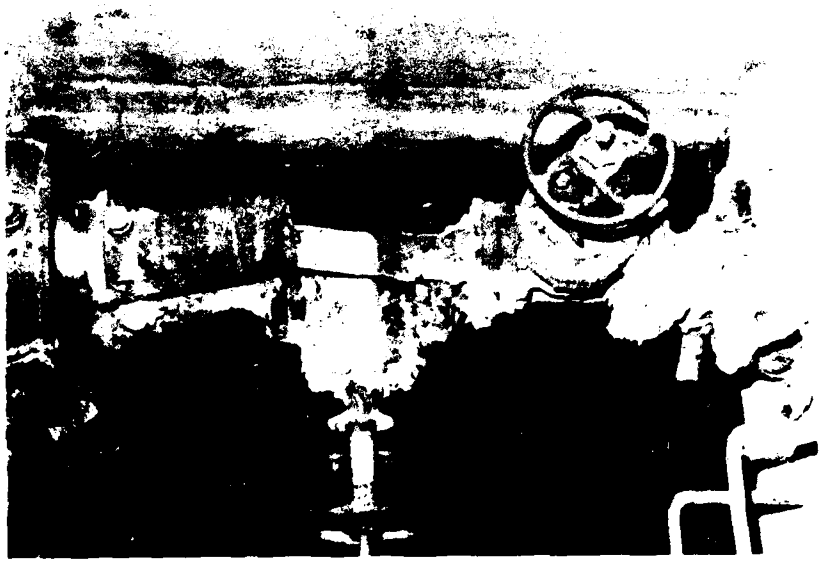

Figure 11. Corroded manhole piping and components (L3-10).

to leak for long periods of time. Using higher-quality valves, which would leak less frequently, should be investigated.

In some manholes, PVC pipes for chilled water were observed to be close to heat distribution piping. Operating personnel stated that in some cases, flooding of a manhole raised the temperature of PVC piping above its softening point, causing it to fail. Thus, there may be a need to investigate whether PVC pipes should be separated from heat distribution pipes by a defined distance or placed in separate manholes.

Drainage. Many manholes with inadequate drainage were observed (Table 5). Efficient operation of prefabricated conduit systems depends on the manhole remaining dry; water in the manholes can cause flooding and corrosion of heat distribution systems and can complicate maintenance operations. Causes of high water in the manholes included plugged drains, failure to install and maintain sump pumps, and failure to prevent entry of surface water into the manhole. Figure 12 shows an example where the water pumped out of a manhole was running back into it. The manhole shown in Figure 13 (over 10 ft deep) was filled with boiling water at the time of inspection.

Ventilation. Manholes with little or no ventilation were observed at several sites (Table 5), apparently because of failure to follow existing design and construction guidance. Figure 14 shows a manhole vent for a 6-year-old conduit system which penetrates the manhole wall below grade and exhausts outside the manhole periphery. Inadequate ventilation aggravates corrosion of the pipes and components in the manholes and interferes with maintenance operations.

Manhole Structure. Many sources of water intrusion into manholes were observed (Table 5). Open-grate tops which allow rainwater to enter manholes present no problems and provide excellent ventilation when sump pumps or gravity drains are operational. However, the entry of surface water into any manhole is detrimental, since it adds to the volume of water which must be removed by the sump pumps and drains, or aggravates flooding if the drainage system is inoperative (Figures 12, 13). Little or no leakage of manhole walls was observed, and current criteria for waterproofing walls seem to be adequate.

Accessibility for Maintenance and Inspection. Many manholes were inaccessible for maintenance and inspection because of flooding (Figure 13), high temperatures, and poor arrangement of components (Table 5). Preventive maintenance of sump pumps and drains and adequate manhole ventilation can allow access of personnel when maintenance is required. Design and construction techniques which allow room for maintenance are required for manholes built in the future.

Penetration of the Heat Distribution System Into Manholes and Buildings

End Plate Coating. Over long periods of time, coatings used on end plates were found to be ineffective in preventing end plate corrosion (Table 5). Severe corrosion of end plates is shown in Figures 15 and 16. Insufficient coating thickness application and coating deterioration were observed on several end plates. End plates should be coated after welding. The coatings

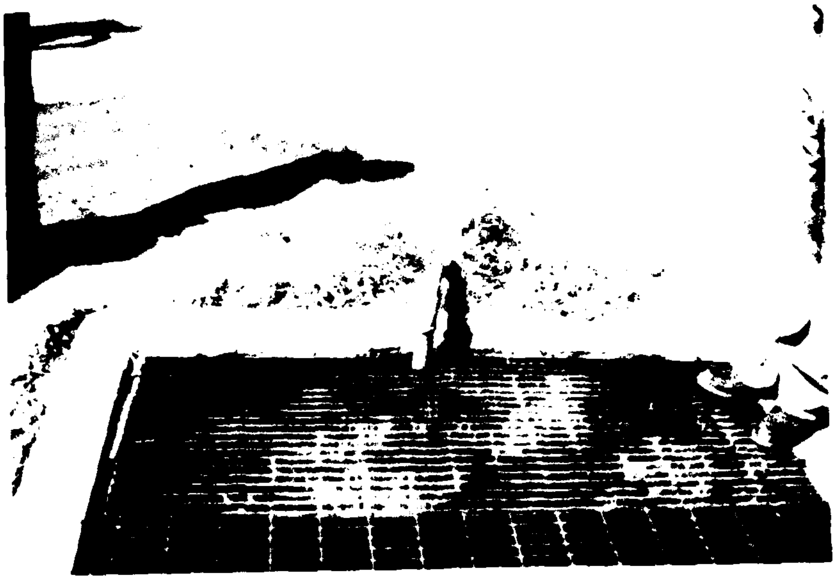

Figure 12. Drainage of surface water into manhole (L3-10).

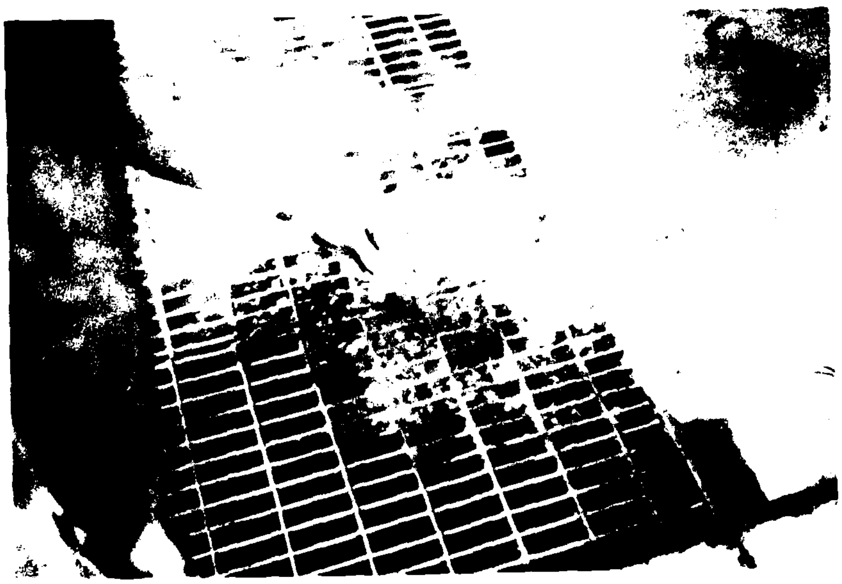

Figure 13. Boiling water in manhole (L8-7).

Figure 14. Vent pipe for conduit interior installed outside manhole (L7-8).

currently used do not appear to work adequately at the high temperatures encountered at the end plate; thus, there appears to be a need for specifying high-temperature coatings for end plates that will be stable at temperatures up to 450°F.

Conduit Drain Opening. Many problems with conduit drains were observed including: no drain openings provided, drain plugs missing or frozen shut, drain ports installed at the sides rather than at the bottom of conduits, and drain plugs inaccessible because of poor component arrangement (Table 5). Most of these problems were the result of design criteria not being incorporated into the design and construction of the manhole. The problem of drain plugs freezing shut because of corrosion can be reduced by using brass rather than steel drain plugs. At one site, a valve was used instead of a plug; however, the use of valves may aggravate the problem of drains freezing shut.

Vent Pipe. Conduit ventilation was found to be inadequate in many instances because of vent pipe problems. Failure to incorporate existing design guidance into design and construction resulted in the vent pipes being placed at the bottom or sides of conduits, failure to install vent pipes, and failure to open vents (Table 5). At several sites, vent pipes did not extend out of the manhole. Although this is a satisfactory arrangement for grate-top manholes, it is not acceptable for concrete- or steel-top manholes, because the vents must be easily observed for evidence of conduit flooding. In one case, check valves were installed in vent lines, which is not allowed by current guidance, since it prevents the vent from steaming if the conduit floods.

Seal Around Conduit. Water intrusion into manholes through seals around the conduits was observed at several sites (Table 5) (Figures 15 and 16).

Figure 15. End plate corroded through (L3-10).

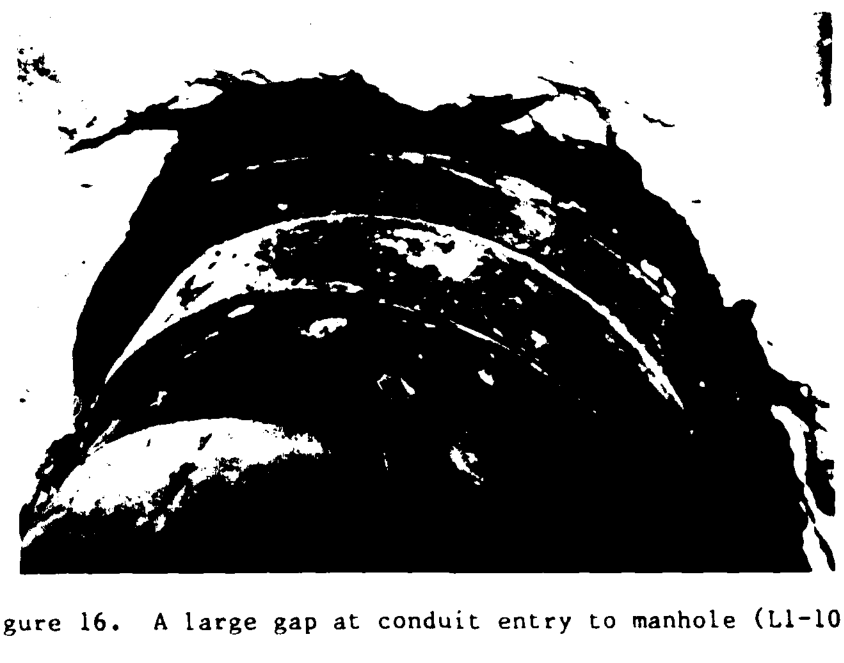

Figure 16. A large gap at conduit entry to manhole (L1-10).

It was concluded that remedial field repairs were not satisfactory and that there is a need for better methods of making and repairing seals. Problems observed included severely deteriorated packing, dried or cracked asphalt, unfilled gaps between the conduit and manhole wall, and charred and cracked link seals.

Conduit

Conduit Coating. The mastic-type conduit coatings appeared to be doing a good job in most cases, but isolated problems were observed. These problems included improper coating system application or selection of materials for the coating, and embrittlement and damage of coatings. Some corrosion of conduits was observed where the coating was damaged. One deficiency in the mastic coating material appears to be its low softening temperature. At several sites, the coating softened and flowed down the conduit; this apparently occurred when water entered the conduit and increased its surface temperature above the softening point of the mastic. The current guidance for conduit coatings appears to be sufficient.

Exterior Surface of Conduit. The exterior surface of some conduits was corroded to various extents, depending on the condition of the coating (Table 5).

Interior Surface of Conduit. The condition of the conduit's interiors differed among sites (Table 5); some had been painted, and others had not. The amount of corrosion was usually mild; but in some cases, pitting was evident. However, there appear to be no serious problems in this area.

Conduit Interior. Water, wet mud, and disintegrated insulation were found in conduit interiors at several sites (Table 5). The mud may have entered the systems during construction, and water often entered through open drain plugs or corroded end plates in manholes. These types of problems occurred because of failure to incorporate existing design criteria into design and construction, and failure to use appropriate maintenance techniques. Corrosion of pipe supports was observed at a few sites; however, this does not appear to be a widespread problem.

Thermal Insulation System

Insulation. The calcium silicate insulation was usually in good condition (Table 5). It appears to maintain its physical strength even when saturated. In some isolated cases, the insulation had broken away from the pipe.

Tie-Straps. The stainless steel tie-straps appeared to be working well, although at several sites, some localized corrosion was observed (Table 5). In one case, the strap had corroded through. It appears that low-quality stainless steel was used in these applications, so there may be a need to specify quality.

Carrier Pipes

Supply Pipe Exterior. The outer surfaces of most of the steel carrier pipes appeared to be in good condition (Table 5). At a few sites, deep pits were observed in systems which had been shut down. The effect of system shutdown or isolation of a line on the life of heat distribution systems is not well understood; some of the corrosion protection of carrier lines occurs because the high temperatures prevent condensation of water on the outside of the line. However, when the system is shut down, the water condenses. The extent to which this can cause aqueous corrosion and appropriate maintenance procedures for avoiding the corrosion have not been identified.

Return Pipe Exterior. Interior corrosion of condensate return lines caused the failure of one system (Table 5). It is well known that condensate return lines are prone to failure if proper water treatment is not used at the boiler plant. In several systems, the steam and return lines were contained in the same conduit. This is not allowed by current criteria because condensate line failures damage steam lines relatively frequently.

Some condensate return lines were found to be uninsulated. Insulation of condensate return lines was not required by CE-301.21; however, this problem has been corrected, since insulation on condensate return lines is now usually required to meet the energy conservation criteria of FCGS 15705.

Above-Ground Systems. Above-ground systems were observed but not inspected at Grand Forks AFB, ND, and at Pensacola NAS, FL (Locations 7 and 8). The systems were in good condition; but it was noted that at Grand Forks AFB water froze in one system during a shutdown of the line in winter, causing extensive damage to the piping. Furthermore, frost heave of the concrete base that supported sections of the system resulted in improper sloping of some sections of the line; this can prevent the system from draining. During a system shutdown in winter, damage to piping can be avoided if the line is drained. Frost heave of concrete foundations can be avoided if proper design and construction techniques are used.

Insulating Powder System

Three systems using insulating powders were observed at Grand Forks AFB, ND (Location 7). Two systems that were 10 years old were found to be in the "not efficient--replace" condition; the other system, which was 11 years old, was in the "efficient with minor problems" or "not efficient--repair" category. It was observed that after long periods of time, the insulating powders react with water, as shown by scale-like deposits.

The observed conditions suggest that current guidance prohibiting the use of this system for new construction is valid.

Shallow Concrete Surface Trench System

Twelve shallow concrete surface trench systems were observed at Fort Bragg, NC; Naval Research Laboratory, Washington, DC; Grand Forks AFB, ND; and Pensacola NAS, FL (Locations 3, 5, 7, and 8, respectively). No soil surveys to determine site classification were made since site classifications were determined subjectively by team members for all the sites except Location 7 using CE-301.21 as a guideline. At Location 7, a soil survey was conducted (Appendix J) and sites were classified according to both CE-301.21 and FCGS 15705.

Eight of the systems were in Class B sites; one system was in a Class A site. The three remaining systems at Location 7 were in Class A sites according to CE-301.21; two of these (Sites 10A and 10B) were in Class B sites, and one (Site 6) was in a Class A site, according to FCGS 15705.

The shallow concrete trench system at Fort Bragg, NC, (four sites) was inefficient because of minor problems associated with 40 years of service in a Class B site. Problems included water in the manholes, corrosion of manhole components, and deterioration of the felt and bituminous coating on the carrier lines. Two of the shallow trench systems (30 years old) at the Naval Research Laboratory, Washington, DC (Class B sites), were inefficient and needed replacement; there were insufficient data to judge the condition of the other two systems, but it is likely that they are inefficient and need repair or replacement. Three shallow trench systems were inspected at Grand Forks AFB, ND; two of these (5 years old) were efficient, and one (3 years old) was inefficient, and needed repair of insulation which had been damaged when a manhole drain froze and caused the system to flood. This could have been prevented by proper installation of the drain below the frost line. At Pensacola NAS, FL, one nonconventional shallow trench system was found to be efficient but having minor problems after 27 years of service in a Class A site. The system consisted of a steel conduit system buried in a shallow concrete trench. The minor problems with the system included flooding, inadequate ventilation of the manhole, and severe corrosion of manhole components.

Buried Concrete Trench System

Four buried concrete trench systems were investigated at Fort Knox, KY, Fort Campbell, KY, and Grand Forks AFB, ND (Locations 1, 2, and 7, respectively). The tops of the trenches were from 2.5 to 5 ft below grade and all systems except the one at Location 7 were installed in Class B sites according to the 1964 guidance (CE-301.21). Site 3 at Location 7 is a Class A site according to current guidance (FCGS 15705 and CE-301.21). The Class B systems were found to serve their design life. However, two systems that were more than 30 years old were "inefficient--replace," while the other two, which were 4 and 23 years old, were found to be "inefficient with minor problems" and "efficient," respectively.

The systems on Class B sites appeared to perform satisfactorily. However, the amount of excavation needed to repair them makes them less attractive than shallow concrete surface trenches or trenches buried slightly below grade.

Fiberglass Reinforced Plastic (FRP) System

One system having steel carrier lines in an FRP conduit was observed at Grand Forks AFB, ND. The system was found to be inefficient and needed replacement after 9 years of service. The FRP had been damaged during a previous excavation; water that entered had not been removed. The conduit drain had rusted shut and there was no conduit vent. Furthermore, the weight of the backfill had deformed the conduit. The results of observing this one system were inadequate for assessing system performance.

Seven systems with conventional prefabricated steel conduit heat distribution lines and FRP condensate return lines were observed at Andrews AFB, MD, and Pensacola NAS, FL (Locations 4 and 8). All these systems were on Class A sites, and only the steam lines were investigated, because field inspection of the condensate return line FRP conduits was impractical.

Half-Round Clay Tile System

Three half-round clay tile systems were inspected at Fort Campbell, KY, and Fort Bragg, NC. All the systems were 26 years old; they were found to be "efficient with minor problems," "not efficient--repair," and "not efficient--replace." It was not possible to tell when the two inefficient systems became inefficient. Most of the difficulties observed with this system were caused by improper sealing at the joints, which allowed water intrusion.

Insulating Concrete System

Inspection of one insulating concrete system at Grand Forks AFB, ND, yielded insufficient data for system evaluation. The system was found to be inefficient and requiring replacement after 26 years in a Class A site; however, it was impossible to determine when the system had failed. The system was not approved for Class A sites at the time of construction and is not approved now. It suffered from damaged waterproofing, entry of water, corrosion of the strengthening wire mesh, and carrier pipe corrosion.

6 EVALUATION OF THE PERFORMANCE OF SYSTEM TYPES INSPECTED

Classifications for the sites investigated were subjectively assessed by the inspection team according to the guidance presented in CE-301.21, except for several sites at Grand Forks AFB, which were evaluated by a soil survey according to both CE-301.21 (1967) and FCGS 15705 (1976) guidance.* Tables 6 through 9 summarize the performance of various types of systems in Class A and Class B sites. The tables show the location, site, age of system, type of system, condition of system, and general comments for the 66 sites investigated. It should be noted that this evaluation does not lend itself to direct statistical analysis, because factors such as numerous site surveys on a single system and the effects of site-specific factors on system performance can bias the results.

Table 6 summarizes the performance of Type A conduits on Class A sites. Of the 26 sites investigated, six were "efficient" or "efficient with minor problems," 11 were "inefficient--repair," and six were "inefficient--replace"; the three remaining sites were classified as "inefficient," but not enough data was available to assess whether repair or replacement was the cost-effective action. Five of the sites at Fort Polk were part of a single system that had failed. Some of these systems could have been reactivated by repairing the casing seams.

Table 7 summarizes the performance of various types of non-Type A systems on Class A sites. The tile, insulating powder coated with stearic acid, and insulating concrete systems that are not approved for Class A or Class B sites were not efficient and needed to be replaced or repaired after 12 to 26 years of service. Two concrete trench systems on Class A sites were observed. One system had served its intended design life and failed after 31 years of service. The other shallow trench system was "efficient with minor problems" after 27 years of service. This system was unique in that a steel-cased system had been installed in a shallow trench.

Table 8 summarizes the performance of Type A systems on Class B sites. Of the 12 systems investigated, ranging from 5 to 16 years of service, 10 were "efficient" or "efficient with minor problems," one was "not efficient--repairable," and one could not be evaluated because of insufficient data. The data show that Type A systems generally performed well on Class B sites.

Table 9 summarizes the performance of non-Type A systems on Class B sites. The 16 concrete trench systems which are approved for Class B sites observed ranged from 4 to 41 years of age. Of the 11 systems in service for more than 25 years, five were "efficient" or "efficient with minor problems," one was not "efficient but repairable," three needed to be replaced, and two were in undetermined condition. The five systems in service less than 25 years ranged from "efficient" to "not efficient needing repair." One system 23 years old was in "efficient" condition; two systems were "efficient with minor problems" and "efficient" after 4 and 5 years, repectively. Another

*The results of the soil surveys and classifications according to FCGS 15705 and CE-302.21 for sites 1, 2, 3, 6, 7, 8, 9, 10 and 11 at Grand Forks AFB, ND are tabulated in Appendix J.

Table 6

Performance of Type A Prefabricated Conduit Systems
On Class A Sites

	Site	System	Age	Condition*	Comment
1.	Ft. Knox, Site 1	C-1	10	B	Manhole drainage, end plates, and vents need maintenance
2.	Ft. Knox, Site 2	C-2	6	C	Improper manhole design, improper vent design No cathodic protection, repairable
3.	Ft. Knox, Site 4	C-1	13	C	Conduit flooding due to corroded sump kit end plates in boiler plant, repairable
4.	Ft. Knox, Site 5	C-1	12	A	No problems
5.	Ft. Knox, Site 6	C-2	14	D	Design and maintenance deficiencies Probably repairable
6.	Ft. Knox, Site 7	C-2	14	C	Manhole internals need work
7.	Ft. Knox, Site 8	C-2	12	B	Manhole flooding, no cathodic protection
8.	Ft. Knox, Site 9	C-1	12	C/D	Very poor design, poor maintenance, no cathodic protection
9.	Ft. Knox, Site 10	C-1	12	C/D	Improper manhole design, open conduit plugs, corroded end plates
10.	Ft. Campbell, Site 2	C-1	4	A	No problems
11.	Andrews AFB, Site 1	C1-FR	9	C	Probably casing leak, systems repairable
12.	Andrews AFB, Site 2	C-1	9	B	No problems
13.	Andrews AFB, Site 3	C-1	11	C	Minor maintenance needed in manhole
14.	Ft. Polk, Site 1	C-1	5	D	Design, construction, and maintenance deficiencies, no cathodic protection
15.	Ft. Polk, Site 2	C-1	5	C	Design, construction, and maintenance deficiencies, no cathodic protection
16.	Ft. Polk, Site 3	C-1	5	C	Design, construction, and maintenance deficiencies, no cathodic protection
17.	Ft. Polk, Site 4	C-1	5	D	Design, construction, and maintenance deficiencies, no cathodic protection
18.	Ft. Polk, Site 5	C-1	5	C	Design, construction, and maintenance deficiencies, no cathodic protection
19.	Grand Forks, Site 7	C-2	15	C/D	Improperly sloped, poor maintenance
20.	Grand Forks, Site 8	C-2	6	D	Improper design, improperly sloped, poor maintenance
21.	Pensacola, Site 1	C1-FR	3	C	System was abandoned; failure due to broken elbow areas; could have easily been repaired; no manhole drainage
22.	Pensacola, Site 2	C1-FR	5	C	No manhole drainage or sump pumps
23.	Pensacola, Site 3	C1-FR	3	C	No manhole drainage or sump pumps; end plates need work
24.	Pensacola, Site 4	C1-FR	7	C	Minor corrosion on casing interior, dry conduit
25.	Pensacola, Site 5	C1-FR	5	D	Casing weld failure
26.	Pensacola, Site 8	C1-FR	8	D	End plate corroded, steam ejector

*Definitions:

A = efficient
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace

Table 7

Performance of Non-Type A Systems on Class A Sites

Site	Age	Type of System	Condition*	Comment
1. Ft. Campbell, Site 1	22	Conduit with steam and return lines in	C	Failure due to internal corrosion of condensate line (mineral wool insulation).
2. Ft. Campbell, Site 3	12	Tile system	B	No insulation was installed on this system. Exterior casing was in good condition, but the system was not providing insulation.
3. Ft. Campbell, Site 4	31	Concrete trench	C	This system served its anticipated life span.
4. Ft. Campbell, Site 5	26	Tile system	C	Failure of joint waterproofing and settling of system. There was extensive insulation damage, and it was impossible to tell how long the system has been inefficient.
5. Grand Forks, Site 1	24	Conduit (C-1) type	B/C	Failure was due to corrosion of nongalvanized field joints.
6. Grand Forks, Site 2	26	Insulating concrete	C	The system was saturated.
7. Grand Forks, Sites 4A & 4B	Unknown	Insulating powder	C	Failure due to improper design and material application.
8. Pensacola, Site 6	27	Shallow trench	A	Unusual system in which a steel-cased system was installed inside a concrete trench.

*Definitions:
A = efficient with minor problems
B = not efficient--repair
C = not efficient--replace

Table 8

Performance of Type A Prefabricated Conduits on Class B Sites

	Site	Age	Condition*	Comment
1.	Ft. Bragg, Site 5	5	B	Some manhole maintenance should be done
2.	Ft. Bragg, Site 6	8	A	Some manhole maintenance should be done
3.	Ft. Bragg, Site 7	8	B	Some manhole maintenance should be done
4.	Ft. Bragg, Site 10	15	C	Manhole work required
5.	Ft. Bragg, Site 11	12	B	Minor manhole work required
6.	NRL, Site 1	5	B	Minor manhole work required
7.	NRL, Site 2	11	B	Minor manhole work required
8.	NRL, Site 3	9	B	Minor manhole work required
9.	NRL, Site 4	9	B	Minor manhole work required
10.	NRL, Site 5	Not Known	B	Minor manhole work required
11.	NRL, Site 6	9	B	Conduit vents should be installed
12.	NRL, Site 7	16	ID	Special application under roadway with conduit enclosed in concrete pipe

*Definitions:
A = efficient
B = efficient with minor problems
C = not efficient--repair
ID = insufficient data to evaluate condition

Table 9

Performance of Non-Type A Systems on Class B Sites

Site	Age	Type of System	FCGS 15705	Condition*	Comment
1. Ft. Knox, Site 3	41	Concrete trench**	N/A	D	Condition as expected due to age
2. Ft. Knox, Site 11	23	Buried concrete** trench	N/A	A	Exceptionally good sump pump maintenance
3. Ft. Bragg, Site 1 Site 2 Site 3 Site 4	35	Concrete trench**	N/A	B	System should be repaired to bring it in line with Tri-Service specifications
4. Ft. Bragg, Site 8	26	Tile	N/A	B	Minor slumping of loose fill insulation
5. Ft. Bragg, Site 9	26	Tile	N/A	C	Trap in manhole
6. NRL Site 8 Site 9 Site 10 Site 11	Over 30 years	Concrete trench**	N/A N/A N/A N/A	D D ID ID	These systems have achieved their expected useful life. The trenches appear sound. If insulation and some piping is replaced and top joint sealing is properly done, additional significant life can be expected.
7. Grand Forks, Site 3	4	Buried concrete** trench	A	B	Requires minor maintenance to flush drains
8. Grand Forks, Site 5		Insulating powder		B/C	Some powder settlement, solidification around pipe, condensate line corrosion.
9. Grand Forks, Site 6	2	Concrete trench**	A	C	Damage due to freezing of drain lines. Design deficiency; system was subsequently repaired
10. Grand Forks, Site 10A & 10B	5	Concrete trench**	B	A	Some maintenance recommended to clear drains

*Definitions:
A = efficient
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace
ID = insufficient data to evaluate condition

**These systems are approved for Class B sites by FCGS 15705. All other systems are not approved for either Class A or Class B sites by CE 301.21 and FCGS 15705.

system was "not efficient requiring repair" after 2 years of operation. This system was damaged when a drain froze, causing trench flooding; it was subsequently repaired and is now perform·.g satisfactorily. The results show that Class B systems performed well on Class B sites without serious problems.

Two concrete trenches (sites 3 and 6) at Grand Forks AFB, ND, were observed on Class A sites as defined by FCGS 15705. The two systems, which were 3 and 4 years old, respectively, were observed to be in "efficient" and "not efficient--repair" condition. The system which needed repair was damaged when a drain in the manhole froze shut, causing flooding at the trench. The system was later repaired. The systems appeared to be working satisfactorily, but they were not old enough to allow an accurate evaluation of the performance of Type B systems on Class A sites.

7 CONCLUSIONS AND RECOMMENDATIONS

Evaluation of System Performance

Type A prefabricated conduit systems were found to be satisfactory on Class A sites when installed in strict compliance with criteria. About half of the systems observed had significant problems which could be attributed to design or construction deficiencies. These problems were compounded by failure to perform preventive maintenance and to take corrective action when problems occurred.

Both Type A and Type B systems were found to perform satisfactorily on Class B sites. Three Type B shallow concrete trench systems were found to be performing satisfactorily on Class A sites as defined by CE-301.21 and Class B sites as defined by FCGS 15705. Two concrete trench systems were observed in Class A sites as defined by FCGS 15705; however, these systems were not old enough to evaluate the performance of Type B systems on Class A sites.

Systems such as insulating concrete and insulating powders did not perform satisfactorily on Class A sites; current guidance does not allow use of these systems on either Class A or Class B sites. Insufficient data were available to assess the performance of Type B systems on Class A sites as defined in FCGS 15705; however, Type B systems appeared to perform satisfactorily on those sites classified as Class A by CE-301.21 and as Class B by FCGS 15705.

Site Classification System

Results of the field inspection indicated that many sites classified as Class A experience high water tables infrequently or not at all. The designation of these sites as Class A may be too stringent, if shallow trench systems can be used satisfactorily. Thus it is recommended that the site classification criteria be reviewed and that the feasibility of allowing shallow trench systems on infrequently submersed sites be investigated.

Prefabricated Conduit System Components

The conclusions and recommendations for the components of the prefabricated steel conduit systems are compiled according to the severity of deficiencies observed and the causes of the deficiencies.

The Tri-Service guidance for the following areas was found to be valid, so there are no recommendations for changes:

1. Conduit exterior coating

2. Conduit interior

3. Pipe supports

4. Calcium silicate insulation

5. Supply pipe exterior

6. Waterproofing of manhole walls.

The Tri-Service guidance was found valid in the following areas; however, when the guidance was not followed, serious problems resulted:

1. Backfill

2. Water entry into manholes

3. Manhole drainage

4. Manhole ventilation

5. Conduit drains

6. Conduit vents

7. Leak detection and identification of type of leak.

Improper backfill techniques aggravated the corrosion of many systems, particularly those in low-resistivity soils. It is recommended that Tri-Service guidance for backfilling be followed.

Inadequate or nonexistent sump pumps and inadequate manhole drainage caused severe corrosion of manhole components, inaccessibility of manholes for maintenance, and premature system failures, particularly when improper use of drain plugs and conduit vents allowed water from manholes to enter the conduits.

Entry of surface water into manholes was observed. Although open-grate-top manholes allow for excellent ventilation, surface water entry into any type of manhole is detrimental. It is recommended that manholes be constructed according to guidance to be established.

Improper use of conduit vents and drains allowed water to enter the conduits and prevented maintenance personnel from checking vents for signs of flooding. Brass drain plugs are required by the Tri-Service Specifications, but in a number of cases, steel drain plugs that had corroded shut were observed. The use of valves in place of drain piping is not recommended.

Following Tri-Service guidance for manhole design, construction, and operation would have prevented some system failures. It appears that establishing periodic preventive maintenance procedures for manholes will be needed to insure proper system operation.

Existing guidance for leak detection and location was not being followed. In many cases, leaks went undetected because vents were plugged or not visible, or because no one inspected them. Specific maintenance deficiencies included failure to attempt repair and failure to pressure-test the conduit to determine whether the leak was in the conduit or the carrier. It is recommended that the Tri-Service Specifications be followed.

The Tri-Service Specifications appeared deficient in certain areas. In some cases, it appeared that further investigation of the problems was necessary; in others, suggested changes to guidance have been made. The deficient areas were:

1. Required cathodic protection for soils with resistivity below 10,000 ohm/cm^3

2. Insulation of condensate return lines*

3. Preventive maintenance of systems

4. The effects of system shutdown on system performance

5. Leak detection and location

6. System slope

7. Manhole design and accessibility

8. Leaking valves in manholes

9. Separation of chilled-water PVC piping and heat distribution piping

10. Coating of conduit end plates

11. Sealing of manhole walls around conduit entry to manholes

12. Selection of tie-strap materials.

Two of the above deficiencies have been corrected by FCGS 15705 which requires cathodic protection when soil resistivity is below 10,000 ohm/cm^3 and usually requires insulation of the condensate return line to meet the energy conservation criteria.

Lack of preventive maintenance and failure to perform required maintenance contributed to many of the system problems observed. Operating personnel were often unaware of appropriate preventive maintenance procedures and lacked the staff to properly maintain the systems. It is recommended that guidance for appropriate maintenance procedures be developed, with an emphasis on contracting out much of the required maintenance.

There are indications that shutdown of systems or isolation of lines can contribute to corrosion. Much of the corrosion protection of the underground heat distribution systems relies on the high temperatures near the carrier lines to prevent aqueous corrosion. However, when the systems are shut down or the lines are isolated, water can condense and cause corrosion. It is recommended that the effects of shutdown on system performance be investigated and any appropriate preventive maintenance procedures be identified.

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*Insulation of condensate return lines is usually required to meet the energy conservation criteria of FCGS 15705.

Operating personnel were not aware of the uses or limitations of state-of-the-art leak detection equipment for conduit systems. It is recommended that they be provided with such information.

Improper sloping of systems was observed, and it appears that the 0.21 percent grade required by CE-301.21 may be too shallow. Increasing the specified grade may provide better system drainage and reduce the chances of improper slope. It is recommended that the feasibility of increasing the grade of the systems be investigated. It should be noted that changing the slope of systems will affect the depth of system burial and the manhole spacing.

Many manholes were found inaccessible for required maintenance because of poor design and construction; prefabricated steel manholes exhibited the worst deficiencies. It is recommended that guidance be developed for manhole designs that allow adequate room and ventilation for all anticipated maintenance and inspection operations. Open-grate manhole tops provide excellent ventilation but require manhole drainage.

Leaking valve stems were observed in several manholes; these valves were often allowed to leak for long periods of time because of the difficulty associated with isolating lines for valve repair. It is recommended that the feasibility of using high-quality valves be investigated.

There was evidence that PVC chilled-water lines near heat distribution piping had failed when manholes flooded because the PVC softened at high temperatures. It is recommended that the effect of proximity of PVC piping to heat distribution piping on the failure of PVC be investigated and guidance developed to address the problem, if necessary.

Coatings on end plates were found ineffective in preventing end plate corrosion for long periods of time. End plates should be coated after welding, and it is recommended that existing guidance be revised to specify high-temperature coatings stable up to temperatures of 450°F for end plates.

Remedial field repairs of manhole walls around conduit seals were found to be ineffective. It is recommended that better techniques be developed for both making and repairing the seals.

Corrosion of stainless steel tie-straps for calcium silicate insulation in conduits was observed at a few sites. It appears that low-quality stainless steel was used, so it is recommended that the possible need for specifying the quality of the tie-strap material be investigated.

Concrete Trench Systems

Twelve shallow concrete trench systems and four buried concrete trench systems were inspected. The systems were found to work satisfactorily on sites designated as Class B by FCGS 15705 and as Class A by CE-301.21. Data were insufficient to evaluate the systems on sites which were designated Class A by both CE-301.21 and FCGS 15705.

Problems observed with the systems included water in manholes and trenches and deterioration of carrier-line insulation and coatings. The proper drainage of manholes is critical to the efficient operation of these systems, since water in the manhole may flood the trench freely. It is recommended that the feasibility of revising criteria to allow these systems on sites with higher water tables be investigated.

Other Systems Investigated

Above-ground systems were observed to be performing well; these systems offer many advantages, but their interference with aesthetics and mobility of personnel and equipment often precludes their use. It is recommended that these systems be considered wherever possible and that less interfering designs be investigated.

Insulating powder and insulating concrete systems which are not approved for Class A or Class B sites did not perform well in general. Although only a few systems were observed, the results suggest that these systems are not suitable for new construction.

The half-round clay tile systems observed were in relatively good condition, but repair is difficult. Because of this difficulty, it appears that their use should be avoided.

Insufficient data were obtained to assess the performance of FRP systems.

APPENDIX A:

SUMMARY OF CRITERIA ESTABLISHED BY CE-301.21 AND FCGS 15705

Summary of Criteria Established by CE-301.21

Site Classification

Two sets of criteria for constructing underground systems are recommended: Class A for wet conditions and Class B for dry conditions.

Class A sites are those where the water table or standing water is expected to be above the bottom of the system at any time. To make this determination, a field investigation is necessary to establish (1) the elevation of the maximum water table, and (2) the probability of surface runoff seeping into the backfilled trench and percolating down toward the underground system at a rate greater than the ability of the ground below the system to carry off the water. This investigation involves making percolation tests and soil borings; identifying underground swales; and determining the probability of flooding or ponding due to local rainfall, snow melting, or irrigation.

Class B sites are those where water or the water table will not rise above the bottom of the system as determined from a detailed survey. The soil in these sites will be coarse-grained with fair-to-excellent drainage characteristics as defined in the unified classification system of Military Standard Mil STD-619B.

Site classification according to CE-301.21 requires a thorough investigation of ground water conditions except where information is available to positively identify the site as Class A or B. If adequate information is not available, a soil survey of the site will be made. Wherever the soil survey indicates that the ground above the bottom of the system between adjacent manholes will be saturated at any time, the site between the manholes will be considered wet, and only Class A systems will be used.

Soil Investigation

The investigation will take note of the probability of surface runoff seeping into the backfill trench and percolating down toward the underground system at a rate greater than the ability of the ground below the system to carry off the water. Determination should be made regarding the probability of flooding the system trench because of normal or wet seasonal high groundwater table or because of local rainfall, melting of snow, or irrigation. Special notice should be taken of those areas where surface ponding may occur either along a sloping surface or in low, flat areas. The permeability of the ground below the level of the system should be ascertained.

Soil Survey

Highest Water Table. The survey will be made, if possible, at the time of year when it is expected that the highest water table will exist.

Formation. The formation of the area along which the underground system is to be laid will be established by borings, test pits, or other suitable means. The explorations should be made at least every 100 ft along the line of the proposed system. If the borings indicate any definite change in the underground conditions between successive holes, such additional borings should be made as necessary to determine the actual underground conditions along the system line. In planning the locations for the explorations, special consideration should be given to slopes, hillocks, and swales that exist along the system line. The explorations should extend below the expected elevation of the system at sufficient distance to ascertain whether seepage from rainfall will flow beyond and below the system or will become perched on an impermeable stratum below the pervious material.

Absorption Test. The proper interpretation of the data obtained from the underground explorations must be carefully made. The following absorption test should be employed to determine whether ground conditions above the bottom of the proposed system will be saturated at any time. Percolation tests should be made along the line of the system at intervals not exceeding 100 ft, and less if the explorations required above indicate appreciable differences in soil percolation characteristics. The tests will be made by digging a hole approximately 1 ft square, or 1 ft in diameter, to a depth of 2 ft below the approximate bottom of the proposed system. This hole will be filled with water to the elevation of the bottom of the proposed system. After the water has completely seeped away, the hole will be immediately refilled with water to the same depth. The time required for the water level to drop 2 in. will be observed and, if this time is 20 minutes or less, the soil will be considered dry (type B site); otherwise, the soil will be considered saturated at times (type A site).

Depth of Water Below System. If the soil fails to meet the percolation test requirements, then no further tests are required and a class A system will be used. If the percolation requirements are met, then the percolation test holes should be deepened an additional 3 ft to determine if the water table is within 5 ft of the bottom of the proposed system.

Cathodic Protection of System. Soil resistivity readings along the proposed line of the underground system should be taken. If soil resistivity readings are less than 3000 ohms per cubic centimeter (ohm/cm^3), cathodic protection should be designed and made a requirement in the contract specification for steel casing systems. If soil resistivity readings are between 3000 and 10,000 ohm/cm^3, a detailed investigation of the need for cathodic protection should be undertaken, and if a decision is made to require cathodic protection it should be designed and made a requirement in the contract specification for steel casing systems.

Soil Stability. As the above surveys are being conducted, observations about the stability of the soil should be noted.

System Watertightness

Class A systems were defined as being a pressure-testable system which is capable of withstanding a 15-lb air-pressure test; Class B systems were defined as being nonpressure-testable.

The watertightness of Type A conduits (for Class A sites) must be proven following construction by maintaining an internal air pressure of 15 psig for a period of 2 hours. In addition, end plates at manholes are required to have vents and drain plugs, and the system is to be designed to maintain a 1-in. air space between the insulation and the outer casing. The vent would permit early detection of water in the system, while the air space and drain would allow draining and drying of the system. Repressurizing the system provides a means for insuring that repairs are effective.

The watertightness of Type B systems (for Class B sites) only has to be proven in a laboratory test. In this test, the conduit would be submerged under a head of water for a period of 24 hours. No test is required to prove the watertightness of Type B systems during construction.

Materials, Design, and Construction

Installers of both Class A and B systems are required to show proof of compliance with specific detailed criteria for materials, design, and construction.

Waterproofing Materials. Waterproofing materials are required to pass a series of laboratory tests to show compliance with minimum standards. Sheet materials are to be tested for tensile strength, tear resistance, shrinkage, resistance to acids and alkalies, permeability, weight loss, and ability to seal after aging. Bitumastic and asphaltic materials are usually used on metallic conduits, since their physical characteristics in underground applications are well known. Thus, the required laboratory tests are limited only to permeability and slump or flow in the anticipated temperature ranges.

Coatings for Metallic Conduits. In addition to the laboratory tests, coatings on metallic conduits must be field-tested with a wire brush holiday detector at between 7500 to 10,000 volts prior to backfilling. In some cases, an outer wrap of asbestos pipeline felt or similar material must be applied on waterproofed metallic casings. The outer wrap on the casings would minimize damage to the coating during shipping, storage, installation, and backfilling.

Strength of Nonmetallic Casings. Nometallic casings are to have minimum crushing strength characteristics as specified in ASTM-C-13. Minimum thicknesses are established for black steel casings, galvanized steel casings, and for joints which require welding.

Insulation. Insulation is to be of a type which could be boiled, drained, and dried and still retain 90 percent of its original thermal efficiency. Specific minimum thicknesses are also indicated.

Joining of Pipes. Criteria to reduce water-caused failures of the heat-carrying pipes include the use of seamless pipes, certification of welders, proper design of loops (including cold springing), limiting the use of dissimilar metals, and hydrostatic pressure tests after installation.

Manholes. Recommendations for manholes include design specifications on manhole drainage, ventilation, waterproofing, access, and working area.

Miscellaneous. Other recommendations consist of design specifications for pipe supports, anchors, system slope, building and manhole connections, and transition to above-ground systems, as well as other system components. Particular attention should be paid to backfilling and compacting trenches. Hand filling and tamping with selected materials to 1 ft above the top of the conduit is a minimal requirement.

Contracting and Inspection Procedures

A manufacturer's representative must be present during critical periods of installation. The representative would supervise construction and bring any problems peculiar to the site to the attention of installation personnel.

The manufacturer certifies that the installation of the conduit system is done in accordance with his recommendations and that the materials used are identical to those which had satisfactorily passed the laboratory tests.

Concrete Trenches

Concrete trench systems are allowed as an option to prefabricated systems in Class B areas, but require the installation of a positive means for manhole drainage.

Summary of Criteria Established by FCGS 15705

Systems Approach to Procurement

The Federal Construction Council undertook the systems approach for the procurement of heat distribution systems whereby the system supplier (ordinarily the manufacturer of one or more of the major elements of the system) assumes responsibility for:

1. Designing and fabricating or specifying all components required for the proper functioning of the system under the conditions in which it is intended to be used

2. Selecting the proper set of components to be employed for a particular project to satisfy the general requirements set forth by the project designer in contract documents

3. Ensuring that the components selected are fabricated and installed properly.

System Design Criteria

To permit a potential bidder on a project to determine whether the system he proposes to supply is generally suitable for the application and, if it is, what specific combination of system components must be supplied and what special precautions must be taken during installation, the project designer should include in contract documents the site condition information specified below. If conditions vary along the proposed path of the system, the project designer should define the conditions for each different segment of the system.

Underground Water Condition Classification. The underground water conditions at a site are classified as severe, bad, moderate, or mild on the basis of the following definitions:

a. Severe (A)--The water table is expected to be above the bottom of the system frequently, or the water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system.

b. Bad (B)--The water table is expected to be above the bottom of the system occasionally, and surface water is expected to accumulate and remain for short periods (or not at all) in the soil surrounding the system; or the water table is expected never to be above the bottom of the system, but surface water is expected to accumulate and remain for long periods in the soil surrounding the system.

c. Moderate (C)--The water table is expected never to be above the bottom of the system, but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.

d. Mild (D)--The water table is expected never to be above the bottom of the system and surface water is not expected to accumulate or remain in the soil surrounding the system.

If at all practicable, a soils engineer familiar with underground water conditions at the site should be employed to establish the classification. Table A1 summarizes the site classifications and the factors which affect site classification.

Soil Corrosiveness Classification. The soils at a site should be classified as corrosive, mildly corrosive, or noncorrosive on the basis of the following criteria:

a. Corrosive--The soil resistivity is less than 10,000 ohm/cm^3, or stray direct currents can be detected underground; all sites classified as having severe water conditions should be classified as corrosive.

b. Mildly Corrosive--The soil resistivity is 10,000 ohm/cm^3 or greater but less than 30,000 ohm/cm^3, and no stray direct currents can be detected underground.

c. Noncorrosive--The soil resistivity is 30,000 ohm/cm^3 or greater, and no stray direct currents can be detected underground.

The classification should be made by an experienced corrosion engineer based on a field survey of the site carried out in accordance with recognized guidelines for conducting such surveys. The results of the field survey should be summarized in a report and submitted by the design organization to the contracting officer with contract documents.

Soil pH. If there is any reason to suspect that the soil pH will be less than 5.0 anywhere along the proposed path of the system, pH measurements should be made at close intervals along the proposed route, and all locations in which the pH is less than 5.0 should be indicated in the contract

Table A1

Site Classification Criteria According to FCGS 15705

Site Class	General Conditions Required for Such Classification	Conditions Found During Site Classification Survey that are Indicative of the Class: Relative to Water Table Level	Relative to Surface Water Accumulation: Soil Types*	Terrain	Precipitation Rates or Irrigation Practices in Area
A--Severe	Water table frequently above bottom of the system within 1 ft of bottom of system	Groundwater	Any	Any	Any
	Water table occasionally above bottom of the system and surface water accumulates and remains for long periods in soil surrounding the system	Groundwater within 5 ft of bottom of system	GC, SC, CL, CH, OH	Any	Any
B--Bad	Water table occasionally above bottom of the system and surface water accumulates and remains either for short periods in soil surrounding the system system	Groundwater within 5 ft of bottom of	GW, GP, SW, SP	Any	Any
			GM, SM, ML, OL, MH		
	Water table never above the bottom of the system, but surface water accumulates and remains for long periods in soil surrounding the system	No ground-water encountered	GC, SC, CL, CH, OH	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
C--Moderate	Water table never above the bottom of the system, but surface water accumulates and remains for short periods in soil surrounding the system	No ground-water encountered	GM, SM, ML, OL, MH	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
			GC, SC, CL, CH, OH	Any except low areas	Equivalent to less than 3 in. in any one month and to less than 20 in. in one year
D--Mild	Water table never above the bottom of the system and surface water does not accumulate and remain in soil surrounding the system	No ground-water encountered	GW, SP, SW, SP	Any	Any
			GM, SM, ML, OL, MH	Any except low areas	Equivalent to less than 3 in. in any one month and to less than 20 in. in one year

*Soil type according to the Unified Soil Classification System.

documents. Soil pH should be determined by an experienced soils engineer, preferably the same engineer responsible for other soils engineering work.

Soil Stability. The load-bearing qualities of the soil in which the system will be installed should be investigated by an experienced soils engineer, again preferably the same engineer responsible for other soils engineering work, and the location and nature of potential soils problems should be identified.

System Requirements

Systems are designed for particular sites. Table A2 summarizes the systems which are suitable for different groundwater conditions according to FCGS 15705.

System Insulation

System insulation requirements should be specified in contract documents in terms of the maximum permissible heat loss, in Btu/ft-hr, for each pipe in each section of the system. The maximum permissible heat loss value should be determined on the basis of an economic analysis performed in accordance with the procedures presented in the Appendix to FCGS 15705 or through use of an agency-supplied computer program. The earth temperature, earth thermal conductivity factor, and depth of burial assumed in the analysis should also be shown in contract documents. Condensate lines should be buried directly without insulation unless their insulation would offer a substantial economic advantage.

Table A2

Types of Systems Suitable for Use with Various Underground Water Conditions (FCGS 15705)

Underground Water Condition	Suitable Types of System Relative to Resistance to Groundwater Infiltration	Suitable Types of System Relative to Resistance to Water Damage
Severe	Air-pressure-testable conduit (15 psig minimum test pressure)	Drainable and dryable
Bad	Air-pressure-testable conduit (15 psig minimum test pressure)	Drainable and dryable
	or	or
	Prefabricated non-air-pressure-testable conduit (capable of resisting a 20 ft head of water)	Water-spread limiting
Moderate	Air-pressure-testable conduit (7-1/2 psig minimum test pressure)	Drainable and dryable
	or either a	or
	Non-air-pressure-testable conduit or an insulating envelope (capable of resisting a 5 ft head of water if a groundwater drainage system is not employed or a 2 ft head of water if a groundwater drainage system is employed)	Water-spread limiting
Mild	Air-pressure-testable conduit (7-1/2 psig minimum test pressure)	Drainable and dryable
	or either a	or
	Non-air-pressure-testable conduit or an insulating envelope (capable of resisting a 1 ft head of water)	Water-spread limiting

APPENDIX B:

SITE INSPECTION DATA AT LOCATION 1, FORT KNOX, KENTUCKY

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Introduction

Eleven sites were inspected at this location, of which nine were prefabricated conduit systems. The other two (sites 3 and 11) were buried concrete trench systems; the top slab at site 3 was removable, but was cast in place at site 11. Of the nine prefabricated systems, four were C-1 systems in which the supply and the return lines were in separate conduits. The remainder were C-2 systems in which the supply and the return lines were in the same conduit. Site 10 was a C-2 system which replaced a C-1 system that had failed after 12 years of operation.

The precipitation at this location averages 46 to 53 in. per year. The soil was mostly heavy red clay with minor sand inclusions. Soil along the excavation was moist. However, there was no evidence of a perched water table at the conduit level. Conduit systems at the nine sites were procured in accordance with the Tri-Service Specification for a Class A underground heat distribution system.

General Observations and Comments From System Users

The soil was quite corrosive in this location. Resistivity values ranged from 1800 to 10,000 ohm/cm^3. Cathodic protection should have been put in according to the Tri-Service Specification; however, none had been installed.

The coatings on the end plates of all the prefabricated conduits were worn away, and some of the end plates were corroded through.

Of the 13 manholes inspected, only the one adjacent to site 11 was dry and had a working sump pump. All the others contained water.

Excavating near the pipes and cutting into the casing revealed that several systems were dry and in good condition. However, water intrusion was apparent at about half the sites.

Site Observation

Site #1

Location. Between Buildings 1725 and 1726; the excavation site was 20 ft from manhole A. Manhole B was located about 250 ft away in a gully 15 ft below excavation.

Date of Inspection. 22 June 1981.

Date of Conduit Installation. 1971.

Age of Conduit. 10 years.

System Description and Known History. The steam line was 4 in. in diameter with 2 in. of calcium silicate insulation. There was 1 in. of annular air space between the insulation and the casing.

This system operated only in winter and was off during the inspection. The steam pressure during operation was 40 psig.*

Excavation Characteristics.

1. Soil Condition: The excavation was in flat terrain. The soil resistivity was 8000 to 10,000 ohm/cm^3.

2. Depth of Burial: 5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: Two adjacent concrete manholes were inspected. Manhole A was 7 ft by 7 ft by 6 ft deep, and manhole B was 7 ft by 7 ft by 12 ft deep. The conduit penetrated into manhole A at 3 ft below grade.

(b) Accessibility: There was no access ladder.

(c) Piping and Components: The insulation and corrugated aluminum covering were in good condition.

(d) Flooding and Drainage: There were 2 ft of water and debris in manhole A, and 3 in. of water and debris in manhole B. There was also a previous watermark at the 2-ft level in manhole B.

(e) Ventilation: Six-in. gooseneck vents were installed in manholes A and B.

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*Use the following metric conversion for measurements used in these appendices: 1 psig = 6.895×10^3 Pa; 1 in. = 2.54 cm; and 1 ft = 30.48 cm.

2. System Penetration:

(a) Accessibility for Maintenance and Inspection: Flooding made the area inaccessible, and there was congestion in the end plate area.

(b) End Plate: No data were obtained.

(c) Waterproof Casing Coating: The coating had deteriorated, and the resultant corrosion on the conduit end plate was severe.

(d) Drainage Opening for Conduit Interior: The opening could not be located.

(e) Vent Pipe for Conduit Interior: Vents on the end plates of the conduits were connected on the bottom of the end plate in lieu of a proper connection on the top plug.

Conduit.

1. Conduit Coating: The conduit coating was chipped off, and some bare surface was exposed. No felt or fiberglass mesh was found.

2. Exterior Surface of Conduit: The exterior surface of the conduit was badly corroded.

3. Interior Surface of Conduit: There was no evidence of corrosion or deterioration.

4. Pipe Support: There was no evidence of excessive heat transfer to the outer casing and no blockage of the drain openings at the support.

Thermal Insulation. The insulation was dry and solid and showed no evidence of deterioration.

Heat-Carrying Pipe. There was no indication of corrosion on the supply pipe exterior.

Site #2

Location. The excavation site was about 30 ft from a manhole located between Buildings 1478 and 1479.

Date of Inspection. 22 June 1981.

Date of Conduit Installation. 1975.

Age of Conduit. 6 years.

System Description and Known History. The steam line was 2 in. in diameter with 1.5 in. of calcium silicate insulation. There was 1 to 1.5 in. of annular air space between the insulation and the casing. The system, which operated continuously, had a steam pressure of 15 psig during the inspection.

Excavation Characteristics.

1. Soil Condition: The excavation was in flat terrain. The soil was extremely corrosive, the resistivity was only 1800 ohm/cm^3.

2. Evidence of Excessive Heat Loss: There was no indication of burned grass which would have been evidence of excessive heat loss. The soil temperature was 103°F at 10 in. below grade at a point directly above the conduit and 82°F 6 ft away from the conduit. The temperature dropped to 72°F 20 ft away from the conduit centerline. The conduit steamed when the opening was cut for the inspection.

3. Depth of Burial: 3.33 ft.

4. Backfill: No selected backfill was used, and no debris was observed.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The size of the concrete manhole was 7.5 ft x 7.5 ft x 7.5 ft deep. The invert of conduit was 4 ft below grade.

(b) Accessibility: The access ladder rungs were severely corroded.

(c) Piping and Components: The piping was severely corroded, and some insulation was missing.

(d) Flooding and Drainage: There were 15 in. of water in the manhole with a previous high waterline at 21 in. A sump pit was provided in the corner of the manhole, but no sump pump was installed.

(e) Ventilation: No ventilation was provided.

(f) Manhole Structure: There was no significant exterior waterproofing.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: No coating was observed. The conduit and end plates were so severely corroded that water was able to enter the conduit.

(c) Vent Pipe for Conduit Interior: There were no vent pipes on the conduit end plates, and the vent opening was plugged.

(d) Seal Around Conduit: The packing between the conduit casing and the concrete wall sleeves was badly deteriorated and might have been the point of entry for water into the manhole.

Conduit.

1. Conduit Temperature: The temperature was measured at 130° to 140°F on the coating and at 160° to 170°F directly on the steel casing.

2. Conduit Coating: Some felt wrapping was peeling off. The bituminous undercoating was held together by fiberglass wrap.

3. Exterior Surface of Conduit: There was no rust or evidence of corrosion.

4. Interior Surface of Conduit: There was uniform corrosion on the conduit's interior surface.

5. Inside of Exposed Surface: A layer of wet mud about 0.5 in. thick was found at the bottom of the casing.

Thermal Insulation. The thermal insulation was dry and intact.

Heat-Carrying Pipes. Scattered corrosion was observed on the supply pipe exterior (estimated at less than 0.005 in. thick); the rust residue scraped off easily.

Site #3

Location. The excavation site was located between Buildings 68 and 87. The site was about 20 ft from a manhole and 30 ft from the building housing the boiler.

Date of Inspection. 23 June 1981

Date of Trench Installation. 1940.

Age of Trench. 41 years.

System Description and Known History. This was a buried concrete trench system with a removable top slab. The internal dimension of the trench was about 1.5 ft wide and 1 ft deep. The concrete cover slab was 3 in. thick and 5 ft long. Inside the trench was a hot water system with two 4-in. lines. This system was operated only in winter and was off during the inspection. The operating water temperature was 160°F.

Excavation Characteristics.

1. Soil Condition: The excavation was in flat terrain. The soil was dark loam and appeared to have excellent percolation characteristics. Although no water table was encountered, the soil was wet at the conduit level. The soil resistivity was 7200 ohm/cm^3.

2. Depth of Burial: The top slab was about 3 ft below grade.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The manhole was constructed of concrete blocks with mortar joints. Although the blocks appeared sound, the joints were badly deteriorated. The dimensions were 7 ft by 7 ft by 5 ft deep. At the manhole entry, the bottom of the trench was 4 ft below grade.

(b) Piping and Components: The uncovered piping and valves were corroded and the valve packings were leaking.

(c) Flooding and Drainage: There was 1 in. of wet mud on the manhole floor, and there was a waterline above the conduit level.

(d) Ventilation: No ventilation was provided.

2. System Penetration: The concrete trench was not sealed at the manhole wall.

Trench.

1. Coating: There was no evidence of waterproofing on the exterior surface.

2. Bottom and Side Slab: The slabs were 4 in. thick and in excellent condition. However, there was a 0.75-in. layer of wet mud on the floor.

3. Top Slab: The top slab was damaged in previous maintenance work and had an 8 in. by 6 in. hole; the soil had entered the manhole at an edge.

4. Joints: The mortar joints between the top slabs had deteriorated, leaving a 1-in. gap at each joint. Mortar used between the top and side slabs was also severely deteriorated.

Thermal Insulation. There was no insulation on the piping.

Heat-Carrying Pipes. Piping was heavily corroded in small areas. Corrosion was particularly severe immediately below the hole in the top slab and at the open joints between the top slabs. Corrosion product buildup was about 0.2 in.

Site #4

Location. The excavation site was between Buildings 2961 and 2963. The site was closer to Building 2963, which housed the boiler. A sump pit located in the boiler plant was inspected.

Date of Inspection. 23 June 1981.

Date of Conduit Installation. 1968.

Age of Conduit. 13 years.

System Description and Known History. The steam line was 2.5 in. in diameter with 2 in. of calcium silicate insulation. There was a 1-in. annular air space between the insulation and the casing. The system was intermittent and was off during inspection. The operating steam pressure was 40 psig.

Excavation Characteristics.

1. Soil Condition: The excavation was in flat terrain, and the soil at the conduit level was moist to wet. The water table was observed about 6 in. below the conduit, and the soil resistivity was 7400 ohm/cm^3.

2. Depth of Burial: 4.5 ft.

Adjacent Sump Pit.

1. Pit Condition:

(a) Arrangement: The concrete sump pit was 5 ft by 5 ft by 6 ft deep. The invert of the conduit at the wall was 4.5 ft below grade.

(b) Piping and Components: All piping and equipment in the sump pit was heavily corroded. Insulation was deteriorated.

(c) Flooding and Drainage: There were about 3.5 ft of water in the pit. The sump pump was inoperative.

(d) Ventilation: There was no ventilation.

2. System Penetration:

(a) End Plate: Data were not obtained.

(b) Waterproof Casing Coating: One end plate was immersed in water, and its paint had peeled off. The plate was corroded through and allowed water to enter directly into the conduit casing.

(c) Vent Pipe for Conduit Interior: There was no vent pipe.

Conduit.

1. Conduit Coating: The felt wrapping and bituminous coating were in excellent condition.

2. Exterior Surface of Conduit: There was no evidence of corrosion.

3. Interior Surface of Conduit: Some minor corrosion was observed.

4. Inside of Exposed Conduit: Water covered the piping in the conduit.

Thermal Insulation.

1. Insulation Material: The insulation was still intact, but was thoroughly saturated because more than half of the conduit was filled with water.

2. Tie-Strap: The stainless steel tie-strap was in good condition.

Heat-Carrying Pipes. The exterior of the supply pipe was corroded, and there was rust on the contacting thermal insulation block.

Site #5

Location. Excavation was about 10 ft from Building 2787. There was no manhole in this area.

Date of Inspection. 23 June 1981.

Date of Conduit Installation. 1969.

Age of Conduit. 12 years.

System Description and Known History. The steam line was 2 in. in diameter with 1.5 in. of calcium silicate insulation. There was a 1- to 1.5-in. annular air space between the insulation and the casing.

The system operated intermittently and was off during the inspection. The operating steam pressure was 30 psig.

Excavation Characteristics.

1. Soil Condition: The excavation was on flat terrain, and the soil was very moist, with some water standing in the area. The soil resistivity was 4800 to 5000 ohm/cm^3.

2. Depth of Burial: 4.5 ft.

Manholes. There were no manholes at this site.

Conduit.

1. Conduit Coating: The coating was in good condition.

2. Exterior Surface of Conduit: There was no evidence of corrosion.

3. Interior Surface of Conduit: There was some minor corrosion.

4. Other Features, Pipe Support: There was very little rust on the pipe support, and there was no blockage of the drain and vent openings in the support.

Thermal Insulation. The insulation was dry and solid and showed no evidence of deterioration.

Heat-Carrying Pipe. There was minor corrosion on the exterior of the supply pipe.

Site #6

Location. The excavation site was near Building 2963, about 20 ft from manhole A.

Date of Inspection. 24 June 1981.

Date of Conduit Installation. 1967.

Age of Conduit. 14 years.

System Description and Known History. The 5-in. steam line and the 2.5-in. condensate return line were in a single 20-in. steel conduit. The insulation on the top of the heat-carrying pipes was 2 in. thick. There was a 1-in. to 1.5-in. annular air space between the insulation and the casing. The system operated only in winter and was off during the inspection. The steam pressure at operation is 30 psig.

Excavation Characteristics.

1. Soil Condition: The soil resistivity was 2400 to 3600 ohm/cm^3 (very corrosive).

2. Depth of Burial: 5 ft.

Adjacent Manholes.

1. Manhole Condition:

(a) Arrangement: Two adjacent concrete manholes were inspected. Manhole A was 7 ft by 7 ft by 7 ft deep; manhole B was 7 ft by 8 ft by 7 ft deep. The invert of the conduit was 4.5 ft below grade for manhole A and 6 ft below grade for manhole B.

(b) Piping and Components: The piping and valves were beginning to rust in manhole A and were severely corroded in manhole B.

(c) Flooding and Drainage: There were 2 in. of water as well as a 12-in. water line in Manhole A. In manhole B, there were 18 in. of water, which reached to the midpoint of the conduit and plate.

(d) Ventilation: There was a 3-in. vent at one corner in manhole A and a 2.5-in. vent at one corner in manhole B.

(e) Manhole Structure: On the exterior surface, only a thin film of black paint was used for waterproofing. According to the guide specification, asphalt or bituminous coatings are required.

2. System Penetration:

(a) End Plate: Data were not obtained.

(b) Waterproof Casing Coating: There was no evidence of a coating, and the end plate in the manhole was corroded through.

(c) Vent Pipe for Conduit Interior: There was no vent pipe installed in manhole A.

(d) Seal Around Pipe: The gland seal flange was severely corroded.

Conduit.

1. Conduit Coating: In some places, the felt wrapping and bituminous coating materials were not properly bonded to the conduit.

2. Exterior Surface of Conduit: There was some pitting on the exterior surface.

3. Interior Surface of Conduit: There was some pitting on the interior surface.

4. Inside of Exposed Conduit: There were 2 in. of water in the conduit.

5. Other Features, Pipe Support: The pipe support was rusted.

Thermal Insulation. Insulation on top of the 5-in. steam line was moist, but not deteriorated; on the bottom 2.5-in. return line, it was saturated. There was some deterioration of the return line insulation.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: There was light pitting on the steam line.

2. Return Pipe Exterior: There was scattered severe corrosion on the condensate return line.

Site #7

Location. The excavation was located 15 ft from manhole A which is closest to Building 5915.

Date of Inspection. 24 June 1981.

Date of Conduit Installation. 1967.

Age of Conduit. 14 years.

System Description and Known History. There were two 4-in., high-temperature hot-water lines in one 20-in. steel conduit. The insulation was 2-in. thick calcium silicate. There was a 1- to 1.5-in. annular air space between the insulation and casing. The system operated only in winter and was off during the inspection. The operating temperature is 375°F.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil resistivity was 7000 to 9000 ohm/cm^3.

2. Depth of Burial: 5 ft.

Adjacent Manholes.

1. Manhole Condition:

(a) Arrangement: Two adjacent concrete manholes were inspected. Manhole A was 7 ft by 7 ft by 7 ft deep; and manhole B was 7 ft by 7 ft by 7 ft deep. The invert of the conduit was 4.5 ft below grade for manhole A and 5 ft for manhole B.

(b) Piping and Components: The piping and valves were heavily corroded. The insulation was deteriorated and had some missing portions.

(c) Flooding and Drainage: Manhole A appeared to have been subjected to repeated flooding.

(d) Ventilation: There were two 6-in. gooseneck vents.

2. System Penetration:

(a) End Plate: Data were not obtained.

(b) Waterproof Casing Coating: The coatings were worn away, and the end plate was severely corroded.

<u>Conduit</u>.

1. Conduit Coating: The coating was in good condition.

2. Exterior Surface of Conduit: The exterior surface was in good condition.

3. Interior Surface of Conduit: The interior surface was in good condition.

4. Inside of Exposed Conduit: The flaky insulation at the bottom was evidence of water intrusion.

<u>Thermal Insulation</u>. Insulation on the top 4-in. line was dry, solid, and in good condition. Insulation on the bottom 4-in. line had some flaking in the lower portion.

<u>Heat-Carrying Pipes</u>. The pipes were in good condition.

Site #8

<u>Location</u>. The excavation was near Building 6017, 15 ft from the manhole.

<u>Date of Inspection</u>. 24 June 1981.

<u>Date of Conduit Installation</u>. 1969.

<u>Age of Conduit</u>. 12 years.

<u>System Description and Known History</u>. There were two 4-in., high-temperature hot-water lines in one 20-in. steel conduit. The insulation was a 2-in. thick calcium silicate block. There was a 1- to 1.5-in. annular air space between the insulation and the casing. The system operated only in winter and was off during the inspection. The operating temperature was 350°F.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil resistivity was 1900 to 2400 ohm/cm^3 (very corrosive).

2. Depth of Burial: 5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimension of the concrete manhole was 7 ft by 9 ft by 8 ft deep. The invert of the conduit was 5.5 ft below grade.

(b) Flooding and Drainage: There were 2 in. of water in the manhole, and there was a watermark about 18 in. above the floor to the bottom of the conduit penetration.

(c) Ventilation: There were two 6-in. gooseneck vents.

2. System Penetration: There was no vent pipe for the conduit interior.

Conduit.

1. Conduit Coating: The coating was in good condition.

2. Exterior Surface of Conduit: The exterior surface was in good condition.

3. Interior Surface of Conduit: The interior surface was in good condition.

4. Other Features, Pipe Support and Field Joint: There was minor rust on the pipe support. The condition of coatings at the field joint was excellent.

Thermal Insulation.

1. Insulation Material: The insulation material was in good condition.

2. Tie-Strap: The tie-strap was in good condition.

Heat-Carrying Pipes. The pipes were in good condition.

Site #9

Location. The excavation was located between the hospital and the nurses' quarters, 40 ft from the manhole.

Date of Inspection. 24 June 1981.

Date of Conduit Installation. 1969.

Age of Conduit. 12 years.

System Description and Known History. The steam line was 5 in. in diameter with 2-in. calcium silicate insulation. There was a 1-in. annular air space between the insulation and the casing. The system operated continuously and, during the inspection, was at a steam pressure of 100 psig.

Excavation Characteristics.

1. Soil Condition: The excavation was located in a valley slightly below the bottom of the manhole. The line extends upward to the nurses' quarters which are about 20 ft above the manhole. The soil was a red clay with minor sand inclusions and was moist to dry at the conduit level. About 30 ft from the manhole, there was a drainage ditch with standing water. The water's elevation was about the same as it was at the bottom of the manhole. The soil resistivity was 6000 to 9000 ohm/cm^3.

2. Evidence of Excessive Heat Loss: An area of burned grass about 3 ft wide along the line of the conduit indicated that there was excessive heat loss from the system. The temperature of the soil was 112°F at 10 in. below grade and directly above the conduit, 88°F at 6 ft from the conduit centerline, and 80°F at 20 ft from the conduit centerline.

3. Depth of Burial: 4.5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The concrete manhole was 8 ft by 12 ft by 12 ft deep. The invert of the conduit was 11.5 ft below grade.

(b) Accessibility: The manhole was too hot to permit entry. The temperature at the top was 140°F and 110°F on the adjacent slab.

(c) Piping and Components: No insulation was left on the piping and accessories. The piping was moderately to heavily rusted.

(d) Flooding and Drainage: There were 4 in. of water in the manhole, with a watermark observed at about 2.5 ft. No gravity drain was found.

(e) Ventilation: None.

(f) Manhole Structure: The exterior manhole walls were not properly waterproofed.

2. System Penetration:

(a) Accessibility for Maintenance and Inspection: The manhole was too hot to enter.

(b) End Plate: Data were not obtained.

(c) Waterproof Casing Coating: The penetration was rusted through, exposing the interior of the casing.

(d) Seal Around Conduit: No effective seal was found.

Conduit.

1. Conduit Temperature: The surface temperature on top of the coating was 150°F and was 180°F after the coating was removed.

2. Conduit Coating: The coating appeared to be somewhat brittle and was not bonded securely to the casing.

3. Exterior Surface of Conduit: There were scattered corrosion spots on the exterior surface.

4. Interior Surface of Conduit: The interior surface was moderately corroded.

Thermal Insulation.

1. Insulation Material: The insulation had deteriorated, and a portion of the pipe insulation had fallen to the bottom of the conduit.

2. Tie-Strap: The tie-strap was severely corroded.

Heat-Carrying Pipes. The exterior of the supply pipe was mildly corroded.

Site #10

Location. Immediately outside of boiler plant.

Date of Inspection. 25 June 1981.

Date of Conduit Installation. 1969.

Age of Conduit. 12 years.

System Description and Known History. The steam line led to a manhole immediately outside the boiler plant and to conduits in the heat distribution system. About 600 ft of line were being replaced. In the abandoned conduit, the steam and condensate pipes were in separate conduits; however, in the new lines, they were in the same conduit. The insulation was calcium silicate, with the old system having a 1-in. air space between the insulation and the casing.

Excavation Characteristics. The boiler plant and the manhole were elevated, and the conduits of the distribution system sloped down from the plant. Difficulty in lining up the conduit may have been caused by using different backfilling procedures for even adjacent trenches.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The concrete manhole was 8 ft by 10 ft by 15 ft deep.

(b) Flooding and Drainage: A watermark was located at the 4.5-ft level (above the conduit end plate). Other watermarks indicate that there were leaks at the manhole corners. No gravity drain or sump pump was observed.

(c) Ventilation: None.

(d) Manhole Structure: The exterior of the manhole was painted with a thin black film; however, the film was not effective as a water or vapor barrier.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: The coating was worn away from the old conduit system. The end plates were heavily corroded and deeply pitted.

(c) Drainage Opening for Conduit Interior: The drain plug was missing.

(d) Vent pipe for Conduit Interior: No pipe was observed.

(e) Seal Around Conduit: There was a large gap between the leak seal and the hole cut at the manhole inlet. This gap could be a potential water intrusion passage if it is not sealed properly.

Conduit.

1. Conduit Coating: There was some blistering and cracking of the coating, indicating a long exposure to high temperatures.

2. Exterior Surface of Conduit: No significant rust or pitting was observed.

3. Interior Surface of Conduit: No significant rust or pitting was observed.

4. Other Features, the Concrete Blocks at the Anchors: The concrete blocks had completely disintegrated to a mass of sand and gravel, apparently because of an improper mix or a heavy rain and trench flooding when the concrete was poured.

Thermal Insulation. Insulation was in good condition in some sections and poor in others. The deterioration of the insulation suggested that submergence and boiling had occurred in the lower portion of the system.

Site #11

Location. Between buildings 2780 and 2778.

Date of Inspection. 25 June 1981.

Date of Trench Installation. 1958.

Age of Trench. 23 years.

System Description and Known History. This was a buried concrete crawl-through trench system with a cast-in-place top slab. The internal dimensions of the trench were about 3 ft wide and 4 to 4.5 ft deep. Inside, there was a 4- to 6-in. steam line and a smaller condensate return line. The two pipes were insulated with fiberglass (about 2 in. thick) wrapped with plastic-coated fiberglass mesh. Team members were unable to determine either the exact construction technique or the extent and type of waterproofing used.

Excavation Characteristics. The terrain was flat. The concrete trench system was buried 4 to 5 ft below an extensively paved area. No excavation was done.

Adjacent Manhole.

1. Manhole Condition: No evidence of flooding was observed. The sump pump on which this system depends to insure drainage was in excellent condition and functioning properly.

2. System Penetration: There was no sealing of the concrete trench at the manhole wall.

Conduit or Trench. The bottom and side slabs appeared to be in excellent condition with no cracking or spalling. There were some drip marks on the wall, and about 1 in. of mud was observed in many places along the trench bottom.

Thermal Insulation. The fiberglass insulation was in good condition, although the jacket was deteriorated in several areas.

Heat-Carrying Pipes. No rust or corrosion was observed.

Summary

Table B1 summarizes the findings of the field investigations at Fort Knox, KY.

Table B1

Summary of Heat Distribution Systems at Fort Knox, KY

Site	System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial (ft)	Soil Resistivity (ohm/cm^3)	Condition*
1	C-1	A	10	steam	5	8-10,000	B
2	C-1	A	6	steam	3.3	1,800	C
3	B-5	B	41	2 HTHW	3	7,200	D
4	C-1	A	13	steam	4.5	7,400	C
5	C-1	A	12	steam	4.5	4800-5000	A
6	C-1	A	14	steam & condensate	5	2400-3600	D
7	C-2	A	14	2 HTHW	5	7-9,000	C
8	C-2	A	12	2 HTHW	5	1900-2400	B
9	C-1	A	12	steam	4.5	6000-9000	C/D
10	C-1 replaced by C-2	A	12	steam & condensate	--	--	C/D
11	B-C	B	23	steam & condensate	4-5	--	A

*Definitions:

A = efficient
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace

APPENDIX C:

SITE INSPECTION DATA AT LOCATION 2, FORT CAMPBELL, KENTUCKY

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Introduction

Five sites and three types of systems were inspected at this location. One site exposed a buried shallow trench system (B-S), and two sites exposed half-round split tile systems (H). The remaining two were prefabricated steel conduit systems. One of the two conduit systems was a 4-year-old C-1 system, and the other was a C-2 system installed prior to the Tri-Service Specification. The precipitation at this location averages 48.2 in. annually.

General Observations and Comments From System Users

The soil was heavy red clay, which was moist at the conduit level; however, there was no evidence of a high or perched water table. The soil resistivity ranged from 6000 to 20,000 ohm/cm^3, but no cathodic protection was provided.

There was no evidence of excessive heat loss at the first four sites since the systems were off during the inspection. However, steaming was observed at site 5 where the system was operating.

According to base personnel, the failure of the condensate pipes in the half-round split tile systems usually occurred because of corrosion from the inside. Occasionally, the outer surface of the pipe would corrode in the area where it was held by a welded clamp.

Sections of the fiberglass-reinforced plastic (FRP) system have separated or sheared in two areas:

1. Near manholes, the shearing resulted from differential settlement.

2. In open areas, problems at joints resulted from differences in thermal contraction during frost conditions.

Site Observation

Site #1

Location. The excavation was located between hangars 7251 and 7252, about 200 ft from the boiler plant.

Date of Inspection. 21 July 1981.

Date of Conduit Installation. 1959.

Age of Conduit. 22 years.

System Description and Known History. The 3-in. steam line and the 2.5-in. condensate return line were mounted vertically in a 16-in. steel conduit. The insulation was 1- to 1.5-in. thick mineral wool encased in a wire mesh. There was more than 1 in. of annular air space between the insulation and the casing. There were no manholes near this site.

This system operated only in winter and was off during the inspection. The system operated at a steam pressure of 60 psig. The conduit had been cut open several months before the inspection and had not been resealed.

Excavation Characteristics.

1. Soil Condition: The terrain was flat and most of the system was covered by concrete slab. Soil resistivity was 20,000 ohm/cm^3. There was standing water near the excavation.

2. Depth of Burial: 2.5 ft.

Manhole. No data were obtained.

Conduit.

1. Conduit Coating: The coating, which appeared to be asphalt, was about 1/8 in. thick and was applied without felt wrapping.

2. Exterior Surface of Conduit: Corrosion was evident.

3. Interior Surface of Conduit: There was some heavy general corrosion with pitting.

4. Other Features, Pipe Support: The conduit was corroded near the insulating concrete supports.

Thermal Insulation. The insulation material and wire mesh were wet, badly deteriorated, and falling off the pipe.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: There was medium-to-heavy corrosion.

2. Return Pipe: The return pipe failed because of internal corrosion, which probably resulted from improper boiler water treatment.

Site #2

Location. The excavation was about 10 ft from the manhole near the new barracks complex addition.

Date of Inspection. 21 July 1981.

Date of Conduit Installation. 1977.

Age of Conduit. 4 years.

System Description and Known History. The steam line was 4 in. in diameter and was covered with 2 in. of calcium silicate insulation. There was 1 in. of annular air space between the insulation and conduit.

This system operated only in winter and was off during the inspection. The steam pressure during operation was 100 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil resistivity was 6000 ohm/cm^3.

2. Depth of Burial: 5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The concrete manhole was about 6 ft by 7 ft by 7 ft deep. The invert of the conduit was 4.5 ft below grade.

(b) Flooding and Drainage: A small amount of mud had entered, but no watermarks were evident.

(c) Ventilation: The raised metal plate permitted a 2-in. air space around the top perimeter of the manhole.

2. System Penetration: No data were obtained.

Conduit.

1. Conduit Coating: The felt wrapping and bituminous coating were in excellent conditon and well-bonded.

2. Exterior Surface of Conduit: The exterior surface was in excellent condition.

3. Interior Surface of Conduit: There was no corrosion on the interior surface.

Thermal Insulation.

1. Insulation Material: The insulation material was dry and solid, with no evidence of deterioration.

2. Tie-Strap: The tie-strap was in excellent condition.

Heat-Carrying Pipe. The pipe was in excellent condition.

Site #3

Location. The site was between Buildings 6804 and 6808. There was no manhole near the site.

Date of Inspection. 21 July 1981.

Date of Installation. 1969.

Age of System. 12 years.

System Description and Known History. The 2-in. steam line and a 1-in. condensate return line were mounted in a conduit composed of a concrete base and covered with half-round tile. There was no evidence that any insulation had been installed.

This system is operated only in winter and was off during the inspection. The system operates at a steam pressure of 40 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was flat.

2. Depth of Burial: 4 ft.

Adjacent Pit Inside the Building. No flooding or drainage of water from the conduit was observed.

Conduit or Tile.

1. Tile and Concrete Pad: The tile and concrete pad were in excellent condition.

2. Waterproof Joints: The conventional mortar used to waterproof joints appeared to work well.

Thermal Insulation. No insulation had been installed.

Heat-Carrying Pipes. The pipes were in excellent condition.

Site #4

Location. Near Building 3212.

Date of Inspection. 21 July 1981.

Date of Conduit Installation. 1950.

Age of Conduit. 31 years.

System Description and Known History. The 2-in. steam line and a 1.5-in. condensate return line were contained in a concrete trench which was 18 in. wide and about 12 in. deep inside. The joints between the top slabs and the side wall were sealed with tar or asphalt. The pipes were covered with 1-in. thick asbestos insulation.

This system operated only in winter and was off during the inspection. The system operates at a steam pressure of 40 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil resistivity was 7320 ohm/cm^3.

2. Depth of Burial: 5 ft.

Condition of Adjacent Pit Inside the Building. There were watermarks in the pit at 2 ft and 3 ft. The sump pump was operable at the time of the inspection. However, the watermarks indicate that pump failures had occurred previously.

Conduit or Trench.

1. Concrete Portion: The concrete portion was in good condition.

2. Joint Area: The tar or asphalt on the joints was dry and peeling and had lost any effectiveness as a waterproofing material.

Thermal Insulation.

1. Insulation Material: The insulation and cloth covering were badly deteriorated, and much of the insulation had fallen off the piping.

2. Tie-Strap: Straps were not made of stainless steel, and some had corroded and broken.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: The supply pipe exterior was heavily corroded and pitted.

2. Return Pipe Exterior: The return pipe exterior was heavily corroded and pitted.

Site #5

Location. West side of Building 6140.

Date of Inspection. 21 July 1981.

Date of Conduit Installation. 1955.

Age of Conduit. 26 years.

System Description and Known History. The 6-in. steam supply line and the 2.5-in. condensate return line were contained in half-round tiles laid over a concrete base. Rock wool insulation was originally packed in to completely fill the void between the pipe and the tile casing.

The system is continuously operating and was on during the inspection. It operates at a steam pressure of 125 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and much of the system was under pavement.

2. Evidence of Excessive Heat Loss: Upon excavation, heavy steaming was noted from the cracks between the tile sections.

3. Depth of Burial: 7 ft.

Adjacent Manhole. The manhole cover was an open grate which allowed surface water intrusion.

Conduit or Tile.

1. Tile and Concrete Pad: The tile was in good condition with little or no deterioration, spalling, or cracking. A 1.5-in. opening between two of the tiles indicated that the concrete base may have settled and cracked.

2. Waterproofed Joints: The waterproofing had deteriorated, leaving an open crack at the tile joints.

3. Inside of Exposed Area: Upon removing the tile, it was found that three-fourths of the system was filled with mud.

Thermal Insulation. The rock wool insulation had almost completely disintegrated, exposing the pipe.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: The supply pipe exterior was in good condition.

2. Return Pipe Exterior: The return pipe exterior was corroded and heavily pitted.

Summary

Table C1 summarizes the findings of the field investigations at Fort Campbell, KY.

Table C1

Summary of Heat Distribution Systems at Fort Campbell, KY

Site	System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Soil Depth of Burial (ft)	Resistivity (ohm/cm^3)	Condition*
1	C-2	A	22	steam & condensate	2.5	20,000	D
2	C-1	A	4	steam	5	6,000	A
3	H	A	12	steam & condensate	4	--	C
4	B-S	A	31	steam & condensate	5	7,320	D
5	H	A	26	steam & condensate	7	--	D

*Definitions:

A = efficient
C = not efficient--repair
D = not efficient--replace

APPENDIX D:

SITE INSPECTION DATA AT LOCATION 3, FORT BRAGG, FAYETTEVILLE, NORTH CAROLINA

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Introduction

Three types of systems on 11 sites were investigated: two were on a deep-buried half-round clay tile system, four were on a shallow concrete surface trench, and five were on a prefabricated conduit system. Four of the conduit systems were C-2 types, and one was a C-1 type.

Fort Bragg receives an average of 48.33 in. of rainfall each year. The soil is mostly sand with clay and has excellent percolation characteristics. There was no evidence of a high water table during the investigation. None of the systems had cathodic protection.

General Observations and Comments From System Users

Open manholes were used extensively. Most of them either had no sump pump or the pump was not working.

Operating personnel stated that leaks were very difficult to find in the prefabricated steel conduit system. The system was also very hard to repair, and the necessary materials were not readily available.

Pipe insulation was found to be highly susceptible to damage from the weather. Insulation in the open manholes and the exposed portions of the shallow trench was badly deteriorated.

Problems caused by the manhole design and maintenance appeared to be the main reason for problems with the underground systems.

The shallow concrete surface trench was the oldest of the three types of systems investigated at this location. Parts of the system were still performing well after 40 years of service, and it had required only minimal maintenance in the 40 years. This system drains by gravity and has not experienced the manhole water problems encountered by the other systems.

Site Observation

Sites #1-#4

Location. The sites were located between Buildings 4T 3028 and 4T 3928 in the same trench line as the hospital. Trenches were exposed at about 200-ft intervals along the line.

Date of Inspection. 29 September 1981.

Date of System Installation. Around 1942.

Age of Conduit. 40 years.

System Description and Known History. The sites were scattered along the 0.5-mile-long shallow concrete surface trench system. The system consisted of a 10-in. steam line and a 5-in. condensate return line. The exterior dimensions of the trench were 76 in. wide and 36 in. deep, and the concrete walls were 6 in. thick. The concrete top was 4 in. thick, with sections about 8 ft long. The top sections could be removed easily for maintenance by using wire rope loops built into the concrete slabs. Insulation consisted of a 1-in. thick asbestos base covered with an asphalt felt.

Thermal expansion in the pipes was absorbed by two internally guided expansion joints. The expansion joint appeared to act as a movable joint and an anchor. Half of the expansion travel could be used by either of the two pipes entering and leaving the joint. The pipe was probably anchored without a joint either at one end or at the center of the section between the two expansion joints. The expansion joint closest to the heating plant was being repacked for the third time during the system's 40-year life, and the second expansion joint was being repacked for the first time in 40 years. The tunnel was equipped with removable flat covers that appeared to be a sidewalk when in place. Metal manhole covers were built into the slab covers over the expansion joints so they could be visually inspected without removing the concrete cover.

The system operated continuously and was on during the inspection at an operating pressure of 100 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil resistivity was as shown in Table D1.

2. Evidence of Excessive Heat Loss: Some burned grass was observed near the joint.

3. Depth of Burial: 3 ft.

AD-A145 181 INVESTIGATION OF TRI-SERVICE HEAT DISTRIBUTION SYSTEMS 2/2
(MODERNIZATION OF..(U) CONSTRUCTION ENGINEERING
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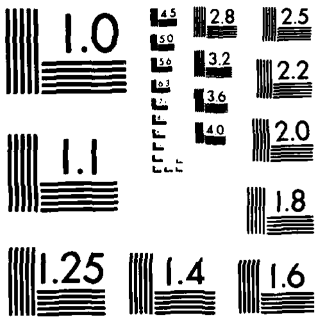

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table D1

Soil Resistivity Data for Sites 1-4 at Fort Bragg, NC

Site	5-ft Depth (ohm/cm^3)	10-ft Depth (ohm/cm^3)
1	22,000	17,000
2	68,000	50,000
3	20,000	28,000
4	48,000	49,000

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 8 ft by 8 ft by 4 ft deep.

(b) Piping and Components: Insulation in the manhole was badly damaged and falling off the piping, which was corroded. The insulation had apparently been damaged by rain which had entered through the grating.

(c) Flooding and Drainage: The sump pump in the manhole was not hooked up.

(d) Ventilation: Ventilation was provided by open gratings on the manholes.

(e) Manhole Structure: The manholes were covered by open gratings. Cracks were observed in the manhole wall.

2. System Penetration: No data were obtained.

Trench.

1. Concrete Portion: Some cracking and spalling were observed on the concrete walls; however, the problem was not serious. One of the concrete top slabs was badly damaged, probably from handling during maintenance operations. No waterproofing membrane was observed on the exterior of the trench.

2. Joint Area: Joints of the covers were butted against one another. They were about 1 in. wide and filled with asphalt, which was dried and cracked.

3. Inside of Exposed Area: The system was gravity-drained, with the trench sloped to allow water that entered the tunnel to drain to either end. Some mud in the bottom of the trench indicated that minor infiltration of surface water had occurred.

4. Other Features, Pipe Supports: Pipe supports on the floor of the trench showed considerable corrosion and pitting. The slip expansion joints were mildly corroded.

Thermal Insulation.

1. Insulation Material: Insulation was generally in excellent condition. However, surface water which had dripped onto the lines from cracks between the top slabs near one expansion joint had damaged both the waterproofing and the insulation.

2. Tie-Strap: Copper circular tie wires placed at about 1-ft intervals were in excellent condition, but the wrapping was dried out and deteriorating.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: Mild corrosion was evident on the heat-carrying pipes, as would be expected of a 40-year-old system. However, this corrosion did not affect the system's operation.

2. Return Pipe: The condensate lines had not been replaced.

Site #5

Location. The system was located at the corner of Normandy Drive and the east entrance to the hospital. The excavation was about 10 ft from the manhole.

Date of Inspection. 29 September 1981.

Date of System Installation. 1976.

Age of Conduit. 5 years.

System Description and Known History. The 4-in. steam line and a 2-in. condensate line were contained in separate conduits. The calcium silicate insulation was 1.5 in. thick. There was a 1-in. annular air space between the insulation and the conduit.

The system was continuously operated and was on during the inspection at a steam pressure of 100 psig. The saturated steam temperature was 337°F.

Excavation Characteristics.

1. Soil Condition: The soil resistivity was 40,000 ohm/cm^3 at 5 ft and 42,000 ohm/cm^3 at 10 ft. The manhole was about 15 ft from the street; the ground sloped away from the manhole to a gully about 5 ft deep.

2. Evidence of Heat Loss: The ground temperature directly above the conduit was 88°F at 8 in. below grade, and 70°F at 20 ft from the conduit centerline. The ambient temperature was about 80°F.

3. Depth of Burial: 3.5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The concrete manhole dimensions were 7 ft by 7 ft by 8 ft deep. The invert of the conduit was 3 ft below grade.

(b) Flooding and Drainage: Watermarks were visible at 15-, 24-, and 35-in. depths. One of the watermarks was above the conduit penetration. The sump pump was unplugged, and the float was unhooked.

(c) Ventilation: Ventilation was provided by an open-grating-type cover.

(d) Manhole Structure: The exterior of the manhole was coated with asphalt or bituminous coating about 1/8 in. thick and was in excellent condition. The manhole cover was an open grating type.

2. System Penetration:

(a) Waterproof Casing Coating: Coatings on conduits and end plates were very thin.

(b) Seal Around Conduit: The seal was packed with asphalt which was dried and cracked. There was space at the penetration where cement was used.

Conduit.

1. Conduit Temperature: The temperature was 105°F on the coating and 125°F directly on the conduit.

2. Conduit Coating: The felt wrapping and bituminous coating were in good condition, but appeared to be thinner than normal.

3. Exterior Surface of Conduit: When the coating was removed, there was no evidence of deterioration or corrosion.

4. Interior Surface of Conduit: The interior surface of the conduit was badly rusted.

5. Inside of Exposed Conduit: A small amount of moist dirt was observed at the bottom of the conduit.

Thermal Insulation.

1. Insulation Material: The insulation was dry and solid and showed no evidence of deterioration.

2. Tie-Strap: The tie-strap was in good condition.

Heat-Carrying Pipes. The pipes were in good condition, and there was no indication of corrosion.

Site #6

Location. Barracks complex.

Date of Inspection. 29 September 1981.

Date of Conduit Installation. 1973.

Age of Conduit. 8 years.

System Description and Known History. The conduit contained a 3-in., high-temperature hot-water (HTHW) supply line and a 3-in. return line. The piping was insulated with 2-in. thick calcium silicate. There was a minimum 1-in. annular air space between the insulation and the casing.

The system operated continuously and, during the inspection, was at a temperature of 375°F.

This system developed a small leak after about 6 years of operation. It took base personnel about 12 to 15 months to find the leak, which was in the draindown portion of the conduit. The water from the leak followed the main conduit to a system building-entry where it was dripping on the floor. After the leak was repaired, the system was dried out and is now performing satisfactorily.

Excavation Characteristics.

1. Soil Condition: The terrain was flat. The soil resistivity at 5 ft below grade was 44,000 ohm/cm^3 and 52,000 ohm/cm^3 at 10 ft.

2. Evidence of Excessive Heat Loss: At 8 in. below grade and directly above the conduit, the ground temperature was 110°F; at 20 ft from the conduit centerline, it was 92°F.

3. Depth of Burial: 29 in.

Manhole. Data were not obtained.

Conduit.

1. Conduit Temperature: The temperature was 140°F on top of the coating and 170°F directly on the conduit.

2. Conduit Coating: The felt wrapping and bituminous coating were in very good condition.

3. Exterior Surface of Conduit: There was no evidence of deterioration on the exterior surface.

4. Interior Surface of Conduit: There was minor rusting but no pitting on the interior surface.

Thermal Insulation.

1. Insulation Material: Insulation was dry and in relatively good condition except for some minor deterioration.

2. Tie-Strap: The tie-strap was in excellent condition.

Heat-Carrying Pipes. The pipes were in excellent condition with no evidence of corrosion.

Site #7

Location. Barracks complex; excavation was near the manhole.

Date of Inspection. 29 September 1981.

Date of Conduit Installation. 1973.

Age of Conduit. 8 years.

System Description and Known Histoy. The conduit contained one 5-in. HTHW supply line and a return line. The calcium silicate insulation was 2 in. thick, and there was a minimum of 1 in. of annular air space between the insulation and the conduit.

This system operated continuously. It was on during the inspection and operating at 375°F.

Excavation Characteristics.

1. Soil Condition: The terrain was flat. The soil resistivity was measured at 44,000 ohm/cm^3 at 5 ft below grade and at 37,000 ohm/cm^3 at 10 ft.

2. Evidence of Heat Loss: The ground temperature was 94°F at 8 in. below grade and directly above the conduit, and 78°F at 20 ft from the conduit centerline.

3. Depth of Burial: 5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 16 ft by 11.5 ft by 10 ft deep. The invert of the conduit was 7 ft below grade.

(b) Piping and Components: A leaking valve was observed.

(c) Flooding and Drainage: Water from a leak in the chilled water valve was in the sump pit and was about 6 in. deep. The open-grate-type cover allowed surface water intrusion.

(d) Ventilation: Ventilation was by an open-grate-type cover.

2. System Penetration:

(a) End Plate: Data were not obtained.

(b) Waterproof Casing Coating: The coating was peeling and corrosion was observed.

(c) Drain Opening for Conduit Interior: The drain plugs needed to be replaced.

Conduit.

1. Conduit Temperature: The temperature was 125°F on the coating and 135°F directly on the conduit.

2. Conduit Coating: The felt wrapping and bituminous coating were in very good condition.

3. Exterior Surface of Conduit: There was no evidence of deterioration on the exterior surface.

4. Interior Surface of Conduit: The interior surface was moderately rusted and pitted, especially at the top of the conduit.

Thermal Insulation. Some pits were observed at the top of the upper section of insulation. The rusty color of the insulation indicated that deterioration was probably caused by dripping condensate.

Heat-Carrying Pipes. The pipes were in excellent condition.

Site #8

Location. Building C 3327. The excavation was about 12 ft from the manhole.

Date of Inspection. 30 September 1981.

Date of Tunnel Installation. 1955.

Age of Tunnel. 26 years.

System Description and Known History. There were two separate half-round clay tile tunnels. One contained a 14-in. steam line, and the other contained a 5-in. condensate return line. The space between the heat-carrying pipe and the half-round tile was filled with mineral wool insulation. Portions of the condensate line had already been replaced, and the rest of the condensate line was being replaced. The steam line, which was located in a separate tunnel, was unaffected by the condensate line failures and in good condition.

The system operated continuously and was on during inspection at a steam pressure of 167 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was relatively flat. The soil resistivity was 40,000 ohm/cm^3 at 5 ft below grade and 30,000 ohm/cm^3 at 10 ft.

2. Evidence of Excessive Heat Loss: There was steaming at the excavation site from the failed condensate line.

3. Depth of Burial: 7 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 12 ft by 16 ft by 10 ft deep. The invert of the conduit was 8 ft below grade.

(b) Piping and Components: Water intrusion resulted partly from leaking valve packing.

(c) Flooding and Drainage: A watermark was observed 3 ft below grade. Water was draining into the manhole from the conduit.

(d) Ventilation: Ventilation was provided by an open-grate-type cover.

(e) Manhole Structure: The open-grate-type cover allowed water intrusion.

2. System Penetration: The seal and tiles were cracked at the conduit penetration.

Tile.

1. Tile Temperature: The temperature of the heat-carrying pipe was 315°F, and the temperature at the top of the tile was 130°F. The tiles were in excellent condition.

2. Waterproof Joints: Joints at the tiles and between the tiles and the concrete base were cemented and then covered with a thick asphalt or bituminous coating. The joints appeared to be in excellent condition.

3. Inside of Exposed Area: The air in the tunnel was damp.

Thermal Insulation. The insulation showed some signs of settling and powdering. However, the tunnel temperatures indicated that the insulation was still performing well.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: The steam pipe was in good condition, with only minimal rust and corrosion.

2. Return Pipe Exterior: Recent condensate line failures were caused by corrosion from the outside. Water probably entered the system through the manhole.

Site #9

Location. Building C 3327, across from site 8 on the other side of the manhole.

Date of Inspection. 30 September 1981.

Date of Tunnel Installation. 1955.

Age of Tunnel. 26 years.

System Description and Known History. The 14-in. steam line was contained in a half-round tile conduit on a concrete base. The space between the heat-carrying pipe and the half-round tile was filled with mineral wool insulation.

The system operated continuously and was on during the inspection at a steam pressure of 167 psig.

Excavation Characteristics.

1. Soil Condition: The terrain was relatively flat, and the soil resistivity at 5 ft below grade was 30,000 ohm/cm^3. The ground temperature was 90°F at 8 in. below grade and above the conduit, and 73°F at 20 ft from conduit centerline.

2. Evidence of Excessive Heat Loss: The water in the adjacent manhole was boiling.

3. Depth of Burial: 6 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 6 ft by 8 ft by 10 ft deep. The invert of the conduit was 7 ft below grade.

(b) Accessibility: It was necessary to step on the pipe to enter the manhole.

(c) Piping and Components: The insulation was deteriorated, the piping was corroded, and the valves or traps were leaking.

(d) Flooding and Drainage: There were 3 ft of water in the manhole. The water drained through the conduit to the manhole at site 8. The sump pump was not operational.

(e) Ventilation: Ventilation was provided by an open-grate-type cover.

(f) Manhole Structure: The open-grate-type cover allowed surface water intrusion.

Tile.

1. Tile: The tile was in excellent condition.

2. Waterproof Joints: The joints at the tiles and between the tiles and concrete base were cemented and then covered with a thick asphalt or bituminous coating. The joints appeared to be in excellent condition.

3. Inside of Exposed Area: The inside of the exposed area was very moist.

Thermal Insulation. The insulation was still filling the space between the heat-carrying pipe and the half-round tile. In some areas, the insulation was somewhat moist and some slumping had occurred; there was also some evidence of powdering, indicating that the insulation was beginning to deteriorate. The temperature inside the tile was comfortable to the touch, indicating that the insulation was still performing well.

Heat-Carrying Pipes. The exterior of the supply pipe was in good condition.

Site #10

Location. The excavation was about 20 ft from the manhole near Building D3225.

Date of Inspection. 30 September 1981.

Date of Conduit Installation. 1966.

Age of Conduit. 15 years.

System Description and Known History. A 16-in. steel conduit contained two 4-in., HTHW lines, insulated with 1.5-in. thick calcium silicate blocks. There was a minimum of 1 in. of annular air space between the insulation and the outer casing.

The system operated continuously and was on during the inspection at a temperature of 380°F.

Excavation Characteristics.

1. Soil Condition: The excavation and manhole were in a low area which collected water from higher ground. The soil was slightly damp at the conduit level, but there was no evidence of a high water table. The soil resistivity at 5 ft below grade was 28,000 ohm/cm^3 and was 27,000 ohm/cm^3 at 10 ft.

2. Evidence of Heat Loss: The soil temperature was 84°F at 8 in. below grade and above the conduit, and 78°F at about 20 ft from the conduit centerline.

3. Depth of Burial: 9 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 6 ft by 10 ft by 10 ft deep. The invert of the conduit was 9 ft below grade.

(b) Piping and Components: The insulation was worn away, and the piping and its components were corroded.

(c) Flooding and Drainage: Team members observed 3 in. of water in the bottom of the manhole during the inspection. Several watermarks were also observed at varying levels, with some located above the conduit penetration into the manhole. The manhole sump pump was often inoperative. It was operating during the inspection, but the water that was pumped from the manhole ran back in due to improper drainage.

(d) Ventilation: Ventilation was provided by an open-grate-type cover.

(e) Manhole Structure: The top of the manhole was at grade, and the open-grate-type cover allowed surface water intrusion.

2. System Penetration:

(a) End Plate: No data were obtained.

(a) Waterproof Casing Coating: The end plates were not properly coated and were corroded through.

(c) Drainage Opening for Conduit Interior: There was no drain port.

(d) Vent Pipe for Conduit Interior: The conduit had no vent piping.

(e) Seal Around Conduit: The caulking was deteriorated and allowed water intrusion.

Conduit.

1. Conduit Temperature: The temperature was 90°F, both with and without the coating.

2. Conduit Coating: The conduit coating was in very good condition.

3. Exterior Surface of Conduit: There was no evidence of deterioration on the exterior surface.

4. Interior Surface of Conduit: There was no pitting or corrosion on the interior surface.

Thermal Insulation.

1. Insulation Material: The insulation was solid and dry, but had some spalling and was severely pitted on the top.

2. Surface Temperature of Insulation: The temperature of the insulation was 108°F, and the pipe surface temperature was 320°F.

Heat-Carrying Pipes. The pipes were in very good condition.

Site #11

Location. Building D3745; the excavation was about 15 ft from the manhole.

Date of Inspection. 30 September 1981.

Date of Conduit Installation. 1969.

Age of Conduit. 12 years.

System Description and Known History. A steel conduit conta[illegible] two 6-in., HTHW lines. They were insulated with 2.5-in. thick calcium [illegible]ate. There was a minimum of 1 in. of annular air space between the ins[illegible]on and the casing.

The system operated continuously. It was on during the inspection and operated at a water temperature of 380°F.

Excavation Characteristics.

1. Soil Condition: The terrain was flat. The soil resistivity was 38,000 ohm/cm^3 at 5 ft below grade and 52,000 ohm/cm^3 at 10 ft. The soil was dry at the conduit level.

2. Evidence of Heat Loss: The ambient temperature was about 80°F. The ground temperature was 110°F at 8 in. below grade and directly above the conduit, and was 78°F at about 20 ft from the conduit centerline.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 24 ft by 24 ft by 8 ft deep. The invert of the conduit was 6 ft below grade.

(b) Flooding and Drainage: No watermarks were observed, and no sump pump had been installed.

(c) Ventilation: Ventilation was provided by an open-grate-type cover.

(d) Manhole Structure: the open-grate-type cover allowed water intrusion.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: The coatings were thin and deteriorating, which caused the end plate to corrode.

(c) Drainage Opening for Conduit Interior: The drain plug was missing.

(d) Vent Pipe for Conduit Interior: A vent pipe was built into the manhole.

Conduit.

1. Conduit Temperature: The pipe surface temperature was 345°F and, at the pipe support, it was 210°F.

2. Conduit Coating: The conduit coating was in excellent condition.

3. Exterior Surface of Conduit: There was mild rust under the coating near the field joint.

4. Interior Surface of Conduit: Very light rust was evident.

Thermal Insulation.

1. Insulation Material: The insulation material was in good condition.

2. Surface Temperature of Insulation: The surface temperature of the insulation was 120°F, and the temperature of the pipe surface was 345°F.

Heat-Carrying Pipes. The pipes were in excellent condition.

Summary

Table D2 summarizes the findings of the field investigation at Fort Bragg, NC.

Table D2

Summary of Heat Distribution Systems at Fort Bragg, NC

Site	System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial	Soil Resistivity (ohm/cm^3)	Condition*
1-4	S-R	B	40	Steam & condensate	3	20-68,000(5 ft) 17-50,000 (10 ft)	B
5	C-1	B	5	Steam & condensate	3.5	40,000 (5 ft) 42,000 (10 ft)	B
6	C-2	B	8	2HTHW	29 in.	44,000 (5 ft) 52,000 (10 ft)	A
7	C-2	B	8	2HTHW	5	44,000 (5 ft) 37,000 (10 ft)	B
8	H	B	26	steam & condensate	7	40,000 (5 ft) 30,000 (10 ft)	B
9	H	B	26	steam	6	30,000 (5 ft) 20,000 (10 ft)	C
10	C-2	B	15	2HTHW	9	28,000 (5 ft) 27,000 (10 ft)	C
11	C-2	B	12	2HTHW	--	38,000 (5 ft) 52,000 (10 ft)	B

*Definitions:
A = efficient
B = efficient with minor problems
C = not efficient--repair

APPENDIX E:

SITE INSPECTION DATA AT LOCATION 4, ANDREWS AFB, MARYLAND

Team Members

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Introduction

Three prefabricated conduit systems were investigated at this location. At sites 2 and 3, the steam and the condensate return lines were in separate conduits. However, the return line at site 1 was made of fiberglass-reinforced plastic (FRP). The FRP return line was buried without any covering.

The precipitation in the area averages 42.8 in. a year. The soil was heavy clay and very moist near the conduit. There was no evidence of a high water table.

The heat distribution system was operated continuously. It was on during the inspection and operating at a steam pressure of 100 psig. Both the steam and the condensate pipes of one of the systems was covered by water, and the conduits were damaged.

General Observations and Comments From System Users

The manholes were all prefabricated metal, and base personnel expressed the following concerns about them: (1) the manholes posed safety problems, (2) the access to valve operator holes was too small, (3) the ventings were not adequate, (4) the entire top of the manholes should be removable, (5) all valves should be upright, (6) access to all manholes should have a key-through cover, and (7) there are no sump pumps.

There were problems with the FRP line at the joints, and there was settling at manholes.

Site Observation

Site #1

Location. Building 3476.

Date of Inspection. 15 December 1981.

Date of Conduit Installation. 1972.

Age of Conduit. 9 years.

System Description and Known History. A steel conduit contained one 8-in. steam line insulated with a 3-in. thick layer of calcium silicate. There was a 1-in. minimum annular air space between the insulation and the casing. The conduit exterior had no cathodic protection. The condensate return line, which was separate, was a 4-in. FRP line with no insulation.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, the soil resistivity was 50,000 ohm/cm^3, and the pH was 5.

2. Evidence of Excessive Heat Loss: Steaming occurred when the opening was cut into the conduit interior.

3. Depth of Burial: 4.5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the prefabricated steel manhole were 7 ft in diameter by 7 ft deep. The invert of the conduit was 4.5 ft below grade.

(b) Piping and Components: The insulation and the aluminum covering were in good condition. The condensate line was not covered with insulation or piping.

(c) Flooding and Drainage: The manhole was dry during the inspection; however, a waterline was observed at 4 ft. Base personnel said that flooding was caused by a corroded and leaking condensate line. The flooding initially occurred several years after installation.

(d) Ventilation: Two hooded vents were installed.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: Small chips of paint were peeling off, and the exposed pipe surface was rusting.

(c) Drainage Opening for Conduit Interior: When the drain plug was removed, water flowed out, indicating that flooding had occurred in the conduit.

(d) Vent Pipe for Conduit Interior: The vent was plugged with dirt.

(e) Seal Around Conduit: The seal was rusted at the weld conduit/manhole-welded interface.

Conduit.

1. Conduit Temperature: The temperature was 160°F on the exterior of the conduit and 300°F on the carrier pipe.

2. Conduit Coating: The felt wrapping and the bituminous layer were in good condition, but there was no asphalt under the mesh.

3. Interior Surface of Conduit: Minor corrosion was evident, which probably resulted from a thin inner coating.

4. Inside of Exposed Conduit: There was about 1 in. of water at the bottom of the conduit.

Thermal Insulation.

1. Insulation Material: The insulation was very wet, but not deteriorated.

2. Surface Temperature of Insulation: The surface temperature of the insulation was 150°F.

Heat-Carrying Pipe. The pipe was in very good condition.

Site #2

Location. The site was near Building 3755 about 15 ft from the manhole.

Date of Inspection. 15 December 1981.

Date of Conduit Installation. 1972.

Age of Conduit. 9 years.

System Description and Known History. The steel conduit contained a 4-in. steam line insulated with 1.5 in. calcium silicate. There was a 1-in. annular air space between the insulation and the casing. Cathodic protection was not installed.

Excavation Characteristics. The terrain was slightly sloped. The soil resistivity was 160,000 ohm/cm^3, and the pH was 4.2.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The prefabricated manhole was 7 ft in diameter by 10 ft deep. The invert of the conduit was 7 ft below grade.

(b) Piping and Components: The piping and components were in excellent condition.

(c) Flooding and Drainage: There were about 12 in. of water in the bottom of the manhole.

(d) Ventilation: Two hooded vents were available for ventilation.

(e) Manhole Structure: The coating on the inside of the steel manhole was in excellent condition; however, the manhole cover was not properly sealed and allowed rainwater intrusion.

2. System Penetration: A gooseneck vent pipe was provided.

Conduit.

1. Conduit Coating: Only kraft paper was applied as a coating.

2. Exterior Surface of Conduit: The exterior surface was rusted.

3. Interior Surface of Conduit: The interior surface was in good condition.

Thermal Insulation. The insulation was dry and solid and showed no evidence of deterioration.

Heat-Carrying Pipe. The exterior of the supply pipe was in excellent condition.

Site #3

Location. Building 3743.

Date of Inspection. 15 December 1981.

Date of Conduit Installation. 1970.

Age of Conduit. 11 years.

System Description and Known History. The steel conduit contained a 6-in. steam line insulated with a 2.5-in. thick layer of calcium silicate. There was 1 in. of annular air space between the insulation and the outer casing. Cathodic protection was installed.

Excavation Characteristics.

1. Soil condition: The terrain was flat. The soil resistivity was not measured, since cathodic protection was provided.

2. Depth of Burial: 9 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the prefabricated steel manhole were 7 ft in diameter by 11 ft deep. The invert of the conduit was 9 ft below grade.

(b) Piping and Components: No insulation was observed, and the components were corroded. Some leaks were observed where pipes were connected to the valves.

(c) Flooding and Drainage: There were 8 to 10 in. of water in the manhole.

2. System Penetration:

(a) End Plate: The end plates were corroded.

(b) Waterproof Casing Coating: No data were obtained.

Conduit.

1. Conduit Temperature: The conduit temperature was 100°F, and the interior pipe temperature was 290°F.

2. Conduit Coating: The coating was deteriorated; no felt wrapping was found, and the amount of asphalt was insufficient.

3. Exterior Surface of Conduit: The exterior surface was rusted.

4. Interior Surface of Conduit: The interior surface was in good condition.

Thermal Insulation.

1. Insulation Material: The insulation material was in good condition.

2. Surface Temperature of Insulation: 60°F.

Heat-Carrying Pipe. The exterior of the supply pipe was in good condition.

Summary

Table E1 summarizes the results of the field inspection at Andrews AFB, MD.

Table E1

Summary of Heat Distribution Systems at Andrews AFB, MD

Site	System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial (ft)	Soil Resistivity (ohm/cm^3)	pH	Condition*
1	C1-FR	A	9	steam	4.5	50,000	5	C
2	C-1	A	9	steam	--	160,000	4.2	B
3	B-1	A	11	steam	9	--	--	C

*Definitions:

B = efficient with minor problems
C = not efficient--repair

APPENDIX F:

SITE INSPECTION DATA AT LOCATION 5, NAVAL RESEARCH LABORATORY, WASHINGTON, D.C.

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Introduction

Eleven sites were investigated at this location, of which four were shallow concrete surface trench systems (S), and seven were prefabricated steel conduit systems (three C-2 and four C-1 systems).

The heat distribution system operated continuously and was on during the inspection at a steam pressure of 100 psi.

The soil was sandy with clay inclusions and was moist at the conduit level; however, there was no indication of a high water table.

General Observations and Comments From System Users

The condition of the 30-year-old shallow trench system was poor. The top of the side wall was below grade, which allowed water intrusion, and the top slab wobbled. However, the users considered the system to be repairable and suggested that it need not be replaced with a conduit system.

Site Observation

Site #1

Location. Between Buildings 57 and 30.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. 1976.

Age of Conduit. 5 years.

System Description and Known History. The steel conduit contained one 6-in. steam line insulated with a 2.5-in. thick calcium silicate block. There was a 1-in. minimum annular air space between the insulation and the casing. No cathodic protection was installed.

Excavation Characteristics.

1. Soil Condition: The terrain was flat; the soil resistivity was 170,000 ohm/cm^3, and the pH was 4.7.

2. Evidence of Excessive Heat Loss: Snow was melting above the line.

3. Depth of Burial: 3 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: This conduit line was connected to a concrete trench 3 ft deep by 4 ft wide. The invert of the conduit was 3 ft below grade.

(b) Piping and Components: Parts of the piping were covered with a 1-in. layer of mineral wool encased in an aluminum jacket. The insulation was generally in good condition; however, some water was dripping from the joints of the concrete slab. The piping and valves were severely corroded, and there was a large steam leak at one of the valve gaskets.

(c) Flooding and Drainage: The manhole was dry. There were no watermarks on the trench wall, but the manhole was very damp because of the steam leak.

(d) Ventilation: No ventilation was provided.

(e) Manhole Structure: The concrete slabs on top of the trench acted as a sidewalk at grade. At the area of conduit penetration into the manhole, the concrete top slabs were replaced by 0.25-in. thick steel plates.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: No drainage opening was provided.

(c) Vent Pipes for Conduit Interiors: No vent pipe was provided.

Conduit.

1. Conduit Temperature: The temperature was 65°F on the conduit surface and 290°F on the pipe surface.

2. Conduit Coating: Only the kraft paper, rather than the 15-lb wrapping, was provided; the fiberglass mesh was very coarse and about 0.75 in. thick.

3. Exterior Surface of Conduit: The exterior surface was in excellent condition.

4. Interior Surface of Conduit: There was only some minor corrosion on the area of the steel surface that was not covered by the coating.

Thermal Insulation.

1. Insulation Material: The insulation material was in excellent condition.

2. Surface Temperature of Insulation: 80°F.

Heat-Carrying Pipe. The supply pipe exterior was in excellent condition.

Site #2

Location. Building 210.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. 1970.

Age of Conduit. 11 years.

System Desciption and Known History. One steel conduit contained a 4-in. steam supply line and a 2.5-in. return line. The steam line was insulated with 2.5-in. thick calcium silicate, but the condensate line was not insulated at all. There was a 1-in. minimum of annular air space between the insulation and the outer casing. No cathodic protection was provided.

Excavation Characteristics.

1. Soil Condition: The terrain was flat.

2. Evidence of Excessive Heat Loss: None was observed.

3. Depth of Burial: 7.5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The concrete manhole was 8 ft by 8 ft by 9 ft deep. The invert of the conduit was 7 ft below grade.

(b) Piping and Components: The internal components and insulation were in good condition. However, the vent pipe was severely corroded at a height of about 3 ft.

(c) Flooding and Drainage: Team members found about 1 in. of water in the bottom of the manhole. Corrosion of the vent pipe indicated that the manhole had apparently been flooded previously.

(d) Ventilation: Ventilation was provided by a raised plate cover with a 2-in. opening around the plate perimeter; the 2-in. opening allowed water intrusion.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: No water was found in the conduit when the brass drain plug was removed; however, minor rust was found on the bottom of the conduit.

Conduit.

1. Conduit Coating: There was no mastic material underneath the fiberglass mesh.

2. Exterior Surface of Conduit: There was no corrosion on the exterior surface.

3. Interior Surface of Conduit: There was no corrosion on the interior surface.

4. Inside of Exposed Conduit: There was evidence of water intrusion and some corrosion in the bottom of the conduit.

Thermal Insulation.

1. Insulation Material: The insulation around the steam pipe had deep pits at the bottom. There was no insulation on the condensate return line.

2. Surface Temperature of Insulation: The surface temperature of the insulation was 110°F, and the temperature of the pipe underneath was 280°F.

Heat-Carrying Pipe. There was slight corrosion on the pipe.

Site #3

Location. Building 1YG2.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. 1972.

Age of Conduit. 9 years.

System Description and Known History. The steel conduit contained a 14-in. steam line insulated with 3-in. thick calcium silicate. There was a 1-in. minimum of annular air space between the insulation and the outer casing. No cathodic protection was provided.

Excavation Characteristics.

1. Soil Condition: The terrain was flat.

2. Depth of Burial: 7 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 5 ft by 5 ft by 8 ft deep. The invert of the conduit was 7 ft below grade.

(b) Piping and Components: The internal components were in good condition.

(c) Flooding and Drainage: There was no evidence of flooding.

(d) Ventilation: Gooseneck vents were provided for ventilation.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: No water drained out of the conduit when the drain plug was removed.

(c) Seal Around Conduit: The link seal between the conduit and the manhole wall was charred and cracked.

Conduit.

1. Conduit Coating: The coating at the field joint was removed for inspection. It was found to be thinner than specified and lacked the fiberglass reinforcing mesh normally specified.

2. Exterior Surface of Conduit: The exterior surface was in excellent condition.

3. Interior Surface of Conduit: The interior surface was in excellent condition.

Thermal Insulation. The thermal insulation was in excellent condition.

Heat-Carrying Pipe. The pipe was in excellent condition.

Site #4

Location. Building A-59.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. 1972.

Age of Conduit. 9 years.

System Description and Known History. The steel conduit contained a 14-in. steam line insulated with 3-in.-thick calcium silicate. There was a 1-in. minimum of annular air space between the insulation and the outer casing. No cathodic protection was provided.

Excavation Characteristics.

1. Soil Condition: The terrain was slightly sloped.

2. Depth of Burial: 5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 10 ft by 10 ft x 8 ft deep. The invert of the conduit was 5 ft below grade.

(b) Piping and Components: The piping and components were in good condition.

(c) Flooding and Drainage: There was no evidence of flooding.

(d) Ventilation: Gooseneck vents were provided for ventilation.

2. System Penetration: The link seal between the conduit and the manhole wall was charred and cracked.

Conduit.

1. Conduit Temperature: The conduit temperature was 100°F, and the surface temperature of the steam pipe was 265°F.

2. Conduit Coating: The coating appeared to be thinner than specified, and no mesh was found. The conduit was covered with impregnated bituminous felt.

3. Exterior Surface of Conduit: The surface was corroded and pitted.

4. Interior Surface of Conduit: The interior surface was in excellent condition.

Thermal Insulation. The insulation had broken away from the steam pipe before the opening was cut into the conduit.

Heat-Carrying Pipes. The pipes were in excellent condition.

Site #5

Location. Building A-69.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. Not known

System Description and Known History. The steel conduit contained one 0.3-in. steam line and one 1.5-in. condensate return line. Both were insulated in a 2.5-in. layer of calcium silicate. There was a 1-in. minimum of annular air space between the insulation and the outer casing. No cathodic protection was provided.

Excavation Characteristics. The terrain was flat; the soil resistivity was 200,000 ohm/cm^3, and the pH was 5.0.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 4 ft by 4 ft by 10 ft deep. The invert of the conduit was 9 ft below grade.

(b) Piping and Components: The piping and components were in good condition.

(c) Flooding and Drainage: There was a small amount of water on the floor of the manhole.

(d) Ventilation: No ventilation was provided.

(e) Manhole Structure: The manhole cover did not have a gasket, which could result in water intrusion.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: There was no drain plug. No water was observed in the conduit.

Conduit.

1. Conduit Temperature: The temperature was 65°F.

2. Conduit Coating: The coating was in excellent condition, having both the proper thickness and felt wrapping.

3. Exterior Surface of Conduit: There was some pitting and corrosion on the exterior surface.

4. Interior Surface of Conduit: The interior surface was in excellent condition.

Thermal Insulation.

1. Insulation Material: The insulation material was in excellent condition.

2. Surface Temperature of Insulation: The surface temperature of the insulation was 70°F.

Heat-Carrying Pipe. The pipe was in excellent condition.

Site #6

Location. Building 69.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. 1972.

Age of Conduit. 9 years.

System Description and Known History. The steel conduit contained a 6-in. steam line and a 2.5-in. compressed air line. The insulation was a 2.5-in. layer of calcium silicate, and there was a 1-in. minimum of annular air space between the insulation and the outer casing. No cathodic protection was provided.

Excavation Characteristics.

1. Soil Condition: The terrain was flat; the soil resistivity was 90,000 ohm/cm^3, and the pH was 4.5.

2. Evidence of Excessive Heat Loss: Some snow was melting along the line of the system, and dry grass was observed in the areas where the snow had melted away.

3. Depth of Burial: 7.5 ft.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 6 ft by 6 ft by 10 ft deep. The invert of the conduit was 8 ft below grade.

(b) Piping and Components: There was some leakage from the pipe.

(c) Flooding and Drainage: The leakage from the pipe drained to the steam ejector sump.

(d) Ventilation: No ventilation was provided.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: No drain plug hole was available.

(c) Vent Pipe for Conduit Interior: No vent pipe was provided.

Conduit.

1. Conduit Coating: The coating was too thin (about 1/16 in.), and the fiberglass mesh was too coarse (about 3/4 in.).

2. Exterior Surface of Conduit: The exterior surface was in excellent condition.

3. Interior of Casing: The interior of the casing had some pitting and corrosion.

4. Inside of Exposed Conduit: There was 1/4 in. to 3/8 in. water at bottom of the conduit.

Thermal Insulation. The thermal insulation was in very good condition.

Heat-Carrying Pipes. The pipes were in good condition.

Site #7

Location. Building 79.

Date of Inspection. 16 December 1981.

Date of Conduit Installation. 1965.

Age of Conduit: 16 years.

System Description and Known History. The steel conduit contained a 6-in. steam line insulated with a 2.5-in. layer of calcium silicate and 1 in. of annular air space. Cathodic protection was provided. The conduit was enclosed by a concrete pipe to protect it from the weight of traffic which was on the street over the system.

Excavation Characteristics. The terrain was flat. No excavation was done since the system was under the roadway.

Adjacent Manholes.

1. Manhole Condition: Manholes A and B were located on opposite sides of the road. Both manholes were made of concrete. The dimensions of manhole A were 4 ft by 4 ft by 9 ft deep, and the dimensions of manhole B were 10 ft by 10 ft by 10 ft deep. The invert of the conduit was 8 ft below grade.

(a) Piping and Components: The piping and components were in good condition.

(b) Flooding and Drainage: Both manholes had minor amounts of water on the floors. No obvious waterlines were found on the walls.

(c) Ventilation: Ventilation was provided for both manholes by raised steel plate covers with open sides.

(d) Manhole Structure: The openings in the manhole covers might allow water intrusion.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: The drain plug in manhole B was missing. A small amount of water was dripping from the conduit, which indicated that water had entered the conduit.

Conduit. No data were obtained.

Thermal Insulation. No data were obtained.

Heat-Carrying Pipe. No data were obtained.

Site #8

Location. Building 56.

Date of Inspection. 16 December 1981.

Date of Trench Installation. Not known.

Age of Trench. Estimated to be more than 30 years.

System Description and Known History. The shallow concrete trench (S-U) was 32 in. wide and 19 in. deep. The concrete covers were about 2 ft long, and the joints between the covers were filled with asphaltic material. The trench was parallel to the street, and the covers were used as sidewalks. The trench contained a 6-in. steam line and a 4-in. return line. Both lines were insulated with 1-in. thick mineral wool.

Excavation Characteristics. The top slabs were not removed for inspection. However, steaming was observed from the manhole and from the joints between the concrete slabs. This indicated that the system is losing large amounts of heat.

Manhole. No data were obtained.

Trench.

1. Concrete Portion: The wall of the trench was deteriorated.

2. Joint Area: The tar sealants were deteriorated.

Thermal Insulation. The mineral wool insulation was damaged by boiling water.

Heat-Carrying Pipe. No data were obtained.

Site #9

Location. Building 12.

Date of Inspection. 16 December 1981.

Date of Trench Installation. Not known.

Age of Trench. Estimated to be more than 50 years.

System Description and Known History. The shallow concrete trench (S-U) was about 6 ft wide and 4 ft deep. The concrete covers were 3 ft long, and the joints between the covers were filled with an asphaltic material. The system was used as a sidewalk. It contained an 8-in. steam line and a 4-in. condensate return line. The insulation was a 2-in. thick layer of calcium silicate covered with an aluminum jacket.

Excavation Characteristics. The terrain was flat. The top slabs were not removed for inspection. A large amount of dead grass along the side of the trench indicated that excessive heat loss had occurred.

Adjacent Manhole. No data were obtained.

Conduit or Trench.

1. Concrete Portion: There were cracks in the concrete.

2. Joint Area: Waterproofing sealants were deteriorated.

3. Bottom of Trench: There was about 1 in. of water along the bottom of the trench.

Thermal Insulation. No data were obtained.

Heat-Carrying Pipes. No data were obtained.

Site #10

Location. Building 102.

Date of Inspection. 16 December 1981.

Date of Concrete Trench Installation. Not known.

Age of Concrete Trench. Estimated to be more than 30 years.

System Description and Known History. The shallow concrete trench (S-U) was about 3 ft wide and 4 ft deep. It was covered with a 1/2-in. steel plate and contained a 6-in. steam line and a 4-in. condensate return line. The insulation was a 2-in. thick layer of calcium silicate covered with an aluminum jacket.

Excavation Characteristics. No covers were opened for the inspection.

Adjacent Manhole. No data were obtained.

1. Joint Area: There were cracks between the top cover plates.

2. Bottom of Trench: There were about 2 in. of water on the trench floor.

Thermal Insulation. No data were obtained.

Heat-Carrying Pipes. No data were obtained.

Site #11

Location. Building 57.

Date of Inspection. 16 December 1981.

Date of Concrete Trench Installation. Not known.

Age of Concrete Trench. Estimated to be more than 30 years.

System Description and Known History. The shallow concrete trench (S-U) was about 3 ft wide and 3 ft deep. The concrete covers, which were used as sidewalks, were about 3 ft long, and the joints between them were filled with an asphaltic material. The system contained an 8-in. steam line and a 4-in. condensate return line. The insulation was a 2-in. thick layer of calcium silicate covered with an aluminum jacket.

Excavation Characteristics. No top slabs were removed to inspect the system.

Adjacent Manholes. No data were obtained.

1. Joint Area: The gaps between the top slabs were at least 1 in. wide.

2. Bottom of Trench: There were at least 2 in. of water at the trench bottom.

Thermal Insulation. No data were obtained.

Heat-Carrying Pipes. No data were obtained.

Summary

Table F1 summarizes the results of the field inspection at the Naval Research Laboratory.

Table F1

Summary of Heat Distribution Systems at the Naval Research Laboratory

Site	System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial (ft)	Soil Resistivity (ohm/cm^3)	pH	Condition*
1	C-1	B	5	steam	3	170,000	4.7	B
2	C-2	B	11	steam & condensate	7.5	--	--	B
3	C-1	B	9	steam	7	--	--	B
4	C-1	B	9	steam	5	--	--	B
5	C-2	B	unknown	steam & condensate	9	200,000	5	B
6	C-2	B	9	steam & compressed air	7.5	90,000	4.5	B
7	C-1 in concrete pipe	B	16	steam	no excavation	--	--	ID
8,9	S-U	B	over 30	steam & return line	--	--	--	D
10-11	S-U	B	over 30	steam & return line	--	--	--	ID

*Definitions:

B = efficient with minor problems
D = not efficient--replace
ID = insufficient data

APPENDIX C:

SITE INSPECTION DATA AT LOCATION 6, FORT POLK, LEESVILLE, LOUISIANA

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Introduction

This field investigation involved excavating five Class A prefabricated steel conduit systems of the C-1 type. The systems contained steam and condensate return lines in separate conduits and were procured in accordance with the Tri-Service Specifications for underground heat distribution systems. All five conduits were installed as part of a major barracks construction contract which began in 1974 and was completed in 1976. The system was procured under Military Contract DACA63-74-B-0188.

This location receives an average of 44 in. of rainfall per year. The soil is clay with a small amount of sand inclusions. In June of 1976, flooding of manholes resulted in failure of polyvinyl chloride (PVC) chilled-water pipes in the manholes. The Corps of Engineers replaced the PVC piping with steel piping at a cost of $84,000. However, at the time of the inspection, no water table was encountered even at the 10-ft-below-grade excavation depth.

The conduit system is a continuously operating system. During the inspection, the steam line was operating at 15 psig, which corresponds to a saturated steam temperature of 250°F. The condensate was being returned to the central heating plant at 98°F.

General Observations and Comments From System Users

The soil resistivity ranged from about 4000 to 10,000 ohm/cm^3, indicating that cathodic protection should have been installed. All steam and condensate lines were in individual steel conduits. Each conduit had an air space of 1 in. or more between the pipe insulation and the conduit shell. All pipe insulation inside the conduits was of the calcium silicate type.

Several design errors, construction errors, and maintenance abnormalities caused problems with the system. All the manholes inspected were of concrete, with no sump pumps and no natural drainage. Thus, water coming into the manholes could enter the conduits. The conduits were often not vented properly, and the drain plugs were often open or nonaccessible. The conduits were also not sloped properly, and water became trapped in the conduits between the manholes.

The design of conduit entries to buildings allowed limited access to drain plugs or vents. The entire system was buried at an unnecessary depth. No sand backfill was used near the conduit, and the drain plugs were not removed periodically as required.

Photographs showed that the system was flooded during construction and that some conduits were submersed in water before they were backfilled. Due to design, construction, and maintenance errors, the system was never dried out properly. The first failure of the condensate pipes, about 3 years after construction was completed, resulted from external corrosion. To compensate for the leaking condensate pipes, operating personnel plugged the vent and drain openings on the conduit and let the conduit cavity fill with condensate return water. The gland seals at the terminal ends of the conduit held the pressure and the conduit shell became pressurized, so the condensate could be returned. Facility personnel were then able to operate the system without repairing the condensate piping. Some of the condensate water which could not drain out of low spots in the conduit was found by the inspection team.

The polyvinyl chloride (PVC) chilled-water lines ran through the same manholes as the steam lines. When the chilled-water pumps were off, the PVC piping became overheated and failed, flooding the manholes and the conduits.

There was some evidence that the asphalt and mastic materials used to coat the outside of the steel conduit shell had too low a softening point. At several locations, the coating materials apparently had softened and were running down the steam pipe.

Comments about the prefabricated steel conduit system were:

1. Facility personnel were not aware of the sensitive nature of this heat distribution system and that its success depended heavily on proper maintenance.

2. There were not enough funds to maintain the system regularly; thus, action was taken only when problems occurred.

3. Facility personnel were frustrated by the difficulty in locating leaks and other system problems.

4. The leaks were difficult to fix and parts had to be ordered from the factory, resulting in labor- and time-intensive repairs.

5. Facility personnel were not furnished with accurate, as-built drawings of the distribution system.

6. Facility personnel were not given adequate information on the required maintenance procedures.

Site Observation

Site #1

Location. The excavation site was in a barracks complex at an expansion loop. The site was located between a manhole and Building 1946, about 90 ft from the manhole.

Date of Inspection. 16 March 1982.

Date of Conduit Installation. 1976.

Age of Conduit. 6 years.

System Description and Known History. The steam line was 6 in. in diameter with a 2.5-in. layer of calcium silicate insulation. There was a 0.75- to 1.5-in. air space between the insulation and the steel conduit shell. The condensate return line was 1.5 in. in diameter with a 1.25-in. layer of calcium silicate insulation.

The chilled-water PVC plastic lines were installed in the same manhole with heat distribution pipes. The conduit vents terminated in the manhole. The diagram in the manufacturer's installation manual showed an optional conduit vent design which also terminated inside the manhole.

Major flooding of manholes occurred due to leaks in the chilled-water lines. This water rose in the manhole until it contacted the hot steam lines, which raised the water temperature to boiling. The boiling water caused failure of the plastic chilled-water piping, causing further flooding in the manhole. The water entered the conduits through inoperative check valves on the vent lines. These check valves not only failed to stop water entry to the conduit during the flooding of the manhole, but they also prevented air circulation before and after flooding. The plastic chilled-water lines in the manholes were eventually replaced with steel pipes, and conduit vents were installed that ended above the manholes. Check valves were not installed on the line as part of the repairs.

Excavation Characteristics.

1. Soil Condition: The terrain is slightly sloping. The soil resistivity 5 ft below grade was 4200 ohm/cm^3, and the soil pH was 4.9.

2. Evidence of Excessive Heat Loss: None was observed.

3. Depth of Burial: 8 ft.

4. Backfill: No selected backfill was used. Rocks, cans, logs, etc., were found.

Adjacent Manhole or Building Entry.

1. Manhole Condition:

(a) Arrangement: There is a concrete curb around three-fourths of the manhole perimeter. If the terrain and manhole top slab tilted toward the manhole, this curb could aggravate rather than eliminate the problem of surface water entry into the manhole. The dimensions of the manhole are 13 ft by 12 ft by 8 ft deep. The invert of the conduit is 5 ft below grade entering the manhole, and 6 ft below grade leaving it.

(b) Accessibility: Piping interfered with access to the manhole, which is too small and poorly arranged.

(c) Piping and Components: The insulation was covered with an aluminum jacket and was in good condition.

(d) Flooding and Drainage: There were 2 in. of water in the manhole and no higher watermarks. Mud and debris collected in the sump pit. The sump pit was used in place of a portable pump which was not installed.

(e) Ventilation: Two 6-in. vents were installed. One extended to the bottom of the manhole top; the other extended into 2 in. of water at the bottom of the manhole, thereby stopping any thermal syphoning which would cool the manhole.

(f) Manhole Structure: The manhole top slab was sloped to the manhole cover, which was flush with the slab surface.

2. System Penetration:

(a) Accessibility for Maintenance and Inspection: Standing water, valves, and bulky insulation materials interfered with the inspection and maintenance of the manhole's end plates. The same obstructions also interfered with maintenance and inspection of the steam lines.

(b) End Plate: The waterproofing coating had deteriorated; corrosion of conduit end plates was severe.

(c) Drainage Opening for Conduit Interior: The conduit drain plug for the condensate lines was difficult to remove because of rust.

(d) Vent Pipe for Conduit Interior: Water flowed from the condensate casing when the valve on the vent line was opened. The draining water indicated that the casing contained water under pressure.

Conduit.

1. Conduit Temperature: The temperature was 113°F on the steam pipe conduit coating and 99°F on the condensate conduit coating. The temperature was 110°F directly on the steel condensate return pipe and 240° on the surface of the steam pipe.

2. Conduit Coating:

(a) Steam Line: On at least one-fourth of the upper quadrant of the conduit, only felt and paper-thin coal tar or asphalt material were observed.

(b) Condensate Line: The coating was in excellent condition.

3. Exterior Surface of Conduit:

(a) Steam Line: Spot corrosion was observed.

(b) Condensate Line: The portion of the condensate line exposed by the opening cut into the conduit was in excellent condition.

4. Interior Surface of Conduit:

(a) Steam Line: Small amounts of corrosion were found on the plate cut out of the conduit.

(b) Condensate Line: There were small amounts of corrosion, with some pitting on the plate.

5. Inside of Exposed Conduit:

(a) Steam Line: There was 0.5 to 1.0 in. of standing water in the conduit.

(b) Condensate Line: The condensate conduit was known to be full before it was opened, and it was known to have leaks. Base personnel allowed the conduit cavity to fill completely with condensate; the conduit shell acted as a pressure vessel and the leaking condensate pipe directed the condensate flow. When the opening was cut in the conduit shell, water spurted out several feet. The shell was allowed to drain before work continued.

6. Other Features, Thermal Expansion Loop Area: The low areas between manholes allowed water to enter the conduit. This was apparently the result of improper sloping of the loop.

Thermal Insulation.

1. Insulation Material:

(a) Steam Line: The insulation was intact except on the bottom of the pipe, where a 1.5-in. thick portion had disintegrated, leaving about a 1-in. layer near the pipe. Holes were observed in the insulation covering the top quadrant of the pipe. The insulation near the pipe surface was a rusty color.

(b) Condensate Line: Although saturated, the insulation remained reasonably intact.

2. Tie-Strap: Only minor rust spots were observed.

3. Surface Temperature: The temperature was 119°F on the wet insulation of the condensate line and 141°F on the steam line insulation.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: Corrosion with some pitting was observed.

2. Return Pipe Exterior: The surface was in good condition at the opening cut into the conduit.

Site #2

Location. Between Buildings 1947 and 1948.

Date of Inspection. 16 March 1982.

Date of Conduit Installation. 1976.

Age of Conduit. 6 years.

System Description and Known History. This system was of the C-1 type, with the steam and condensate lines in separate conduits. An opening was cut in the steam conduit near a pipe support. The steam pipe was 5 in. wide with 2 in. of insulation. The conduit was previously flooded because a break in the chilled-water lines caused water to back up into the system. No action was taken to drain and dry the conduit.

Excavation Characteristics.

1. Soil Condition: The terrain is flat. Soil resistivity at 5 ft below grade is 8000 ohm/cm^3, and the soil pH is 5.0. The soil is classified as corrosive.

2. Evidence of Excessive Heat Loss: None was observed.

3. Depth of Burial: 4 ft.

4. Backfill: No sand was used in the backfill, but junk materials (rocks, rebars, logs, etc.) were found.

Adjacent Manhole or Building Entry. The manhole was not accessible and therefore not inspected. The other end of the conduit terminated at a building crawl space. The end plate was covered by silt, and the drain plug could not be found.

Conduit.

1. Conduit Temperature: The temperature of the exterior surface of the casing immediately over the pipe support was 192°F.

2. Conduit Coating: The coating on the top quadrant of steam pipe appeared to be about one-half of the required thickness. However, the coating

on the conduit invert was thicker than required. Apparently, it had softened and flowed to the invert when the casing became overheated.

3. Exterior Surface of Conduit: A rust spot about 1 in. wide was found on the surface of the conduit.

4. Interior Surface of Conduit: There was minor rust, but no pitting.

5. Inside of Exposed Conduit: There was 1 in. of water inside the conduit.

6. Other Features, Pipe Support: The pipe support was rusted.

Thermal Insulation.

1. Insulation Material: The insulation was damp, but not saturated. Dripping condensation had eroded holes into the insulation covering the top of the pipe.

2. Tie-Strap: The steel tie-strap had corroded through.

3. Surface Temperature of Insulation: The temperature was 168°F.

Heat-Carrying Pipe. The exterior of the steam line showed some minor corrosion, but no pitting.

Site #3

Location: Northeast corner of Building 2048.

Date of Inspection. This site was excavated on 16 March 1982 and inspected on 17 March 1982.

Date of Conduit Installation. 1976.

Age of Conduit. 6 years.

System Description and Known History. Only the steam line was inspected at this site. The conduit contained an 8-in. steam pipe, with a 2.5- to 3-in. thick layer of calcium silicate insulation. A minimum of 1 in. of air space separated the insulation from the conduit. The invert of the conduit at excavation was 10 ft below grade.

This site was selected because base personnel suspected that it was an undrained low spot in the system. They also thought that the conduit section had been flooded several times because of a broken chilled-water pipe.

Excavation Characteristics.

1. Soil Condition: The terrain was sloped. The site elevation was higher than that of the adjacent manhole near the central energy plant. The soil resistivity 5 ft below grade was 7000 ohm/cm^3, and the soil pH was 5.7. The soil was classified as corrosive.

2. Evidence of Excessive Heat Loss: No burned grass was observed above the conduit. Steaming was observed during the excavation.

3. Depth of Burial: 10 ft.

4. Backfill: No special backfill was used to surround the conduit in this plastic clay environment.

Adjacent Manhole.

1. Manhole Condition:

(a) Accessibility: Not accessible for proper maintenance.

(b) Piping Condition: Insulation on the piping had worn away as a result of individuals stepping onto the pipe when entering the manhole. The heat-carrying pipes in the manholes were improperly insulated with fiberglass insulation and plastic jackets.

(c) Flooding and Drainage: Neither of the adjacent manholes had a sump pump, and each manhole contained standing water.

(d) Ventilation: Vents were installed properly in each manhole. However, one vent was flush with the bottom of the manhole top; the other extended all the way through the water.

(e) Manhole Structure: A thin manhole cover was used to replace a thicker, heavier cover. The thin cover worked as a catch basin for collecting water which entered the manhole.

2. System Penetration:

(a) Accessibility for Maintenance and Inspection: Poor.

(b) End Plate: No data were obtained.

(c) Waterproof Casing Coating: Deteriorated.

(d) Drain Opening for Conduit Interior: The conduit drains were "elbowed-down" and were open. The drains should have been plugged.

(e) Vent Pipe for Conduit Interior: Vent pipes extending through the manhole top were properly installed after flooding occurred.

(f) Seal Around Conduit: Not easily visible.

Conduit.

1. Conduit Temperature: The temperature was 179°F after removal of the coating.

2. Conduit Coating: The coating on the top quarter of the steam pipe was very thin.

3. Exterior Surface of Conduit: Pitting and blistered corrosion areas were observed on the top and side of the conduit where the coating was very thin. A rust spot thickness was measured and was found to have decreased conduit wall thickness by 50 percent.

4. Interior Surface of Conduit: There were small amounts of corrosion, but no pitting was observed on the plate cut from the conduit.

5. Inside of Exposed Conduit: There were about 3 in. of water in the bottom of the conduit. The water covered part of the insulation.

6. Other Features, Thermal Expansion Loop: When the opening was cut into the conduit, steaming was observed. The steaming continued so rapidly that it was difficult to conduct the inspection. Several inches of water were standing inside the conduit. The drains were open in the manholes on each side of the site, but no water was flowing out of them. This indicated either a low point or a plugged drain path.

Thermal Insulation.

1. Insulation Material: The insulation was not removed from the pipe because of the hot steaming conditions. The insulation was saturated and soft to the touch; however, it had retained its general shape on top of the pipe. There was some white sediment mixed with the water standing in the conduit which was thought to be dissolved insulation.

2. Tie-Strap: The tie-strap was in good shape.

3. Surface Temperature of Insulation: The temperature was 168°F on top of the insulation.

Heat-Carrying Pipe. Because of steaming at the opening of the conduit, it was not possible to inspect the heat-carrying pipe.

Site #4

Location. Between Building 2047 and 2041.

Date of Inspection. 17 March 1982.

Date of Conduit Installation. 1976.

Age of Conduit. 6 years.

System Description and Known History. Only the condensate return line was opened at this site. The diameter of the condensate return line was 1.25 in., with 1.5 in. of calcium silicate thermal insulation. This conduit, which had the required 1-in. air space, was full of water from a broken condensate pipe. Maintenance personnel decided to pressurize the casing by closing the vents and drains at the adjacent manholes, rather than locate and repair condensate line leaks. Water spurted out of the conduit when the inspection opening was cut.

Excavation Characteristics.

1. Soil Condition: The terrain is slightly sloped. Soil resistivity is 10,000 ohm/cm^3, and the soil is classified as mildly corrosive. The soil pH is 4.0.

2. Evidence of Excessive Heat Loss: None observed.

3. Depth of Burial: 4 ft.

4. Backfill: Selected backfill was not used.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The size of the manhole was 9 ft by 10 ft by 8 ft deep. This manhole was waterproofed with a vinyl sheet about 0.003 in. thick which was attached to the manhole with a mastic sealant.

(b) Accessibility: It was necessary to step on piping for entry and maintenance.

(c) Piping and Components: The insulation was in good condition and was covered with an aluminum jacket.

(d) Flooding and Drainage: There were about 6 in. of water in the bottom of the manhole. There was no sump pump and the sump was filled with mud and debris.

(e) Ventilation: There are gooseneck vents for the bottom and top of the manhole.

2. System Penetration:

(a) Accessibility for Maintenance and Inspection: Access to the drain plugs in the manholes was extremely difficult. The location of valve flanges, piping, and insulation made unscrewing the drain plugs very difficult.

(b) End Plate: No data were obtained.

(c) Waterproof Casing Coating: Minor corrosion was noted.

(d) Drain Opening for Conduit Interior: After shutting off the main condensate line valve, the drain plug was opened for the inspection. Water drained from the conduit into the manhole.

Conduit.

1. Conduit Temperature: The temperature was 112°F on top of the coated steam line conduit, 127°F on top of the uncoated steam line conduit, and 108°F on top of the coated condensate pipe conduit.

2. Conduit Coating: The mastic coating on the condensate pipe appeared to have been installed properly and was of the proper thickness. The coating on the steam conduit was very thin and appeared to be only fiberglass fabric and a thin layer of mastic.

3. Exterior Surface of Conduit: A corrosion pit 0.025 in. deep was discovered on the exterior of the condensate conduit shell.

4. Interior Surface of Conduit: The inside of the conduit was in good condition with only mild corrosion and minor pitting.

5. Inside of Exposed Conduit: The conduit was full of water.

Thermal Insulation. The insulation was saturated with water and had green and brown spots near the pipe surface. However, it was still intact.

Heat-Carrying Pipe. The exterior of the condensate pipe was heavily corroded and pitted. There appeared to have been some reaction between the pipe and the pipe insulation while they were submersed in the water. The condensate pipe was judged to be a total failure. Similar corrosion was observed at an earlier condensate line failure.

Site #5

Location. This site was located near Building 1566 on an "expansion-elbow" between Buildings 1566 and 1564.

Date of Inspection. 17 March 1982.

Date of Conduit Installation. 1976.

Age of Conduit. 6 years.

System Description and Known History. Only the steam line was inspected at this site. The steam pipe was 6 in. in diameter with 2.5 in. of calcium silicate insulation. There was a 1-in. annular air space between the insulation and conduit.

Excavation Characteristics.

1. Soil Condition: The terrain is flat. Soil resistivity at 5 ft below grade is 7000 ohm/cm^3, and the soil is classified as corrosive. The soil pH is 4.8.

2. Evidence of Excessive Heat Loss: There was some dead grass above the route of the conduit, which indicated that excessive heat loss had occurred. The ground temperature immediately above the conduit was 101°F; the temperature 10 ft from the conduit centerline was 86°F. The soil was extremely dry and hard at the depth of the conduit.

3. Depth of Burial: 3 ft.

4. Backfill: No selected backfill was used.

Adjacent Manhole or Building Entry.

1. Manhole Condition: The manhole adjacent to Site #5 was not accessible for inspection. Another manhole near Building 1568 had steaming and boiling water covering all the valves. Base personnel suspected that the chilled-water line had broken.

2. System Penetration (entry in crawl space of Building 1566 adjacent to site):

(a) Accessibility for Maintenance and Inspection: The system was drained by opening the drain plug at the interface of the building wall in the crawl space. Access to the end plate was through 100 ft of crawl space under the building. The vent line also terminated in the crawl space, which made it very difficult to make periodic maintenance inspections. When initially opened, the drain was clogged with material that appeared to be pieces of soggy insulation. When this material was dislodged, 5 to 10 gal of water flowed out of the conduit. The vent and drain openings were plugged and inaccessible. The system was not constructed according to the shop drawings.

(b) Drain Opening for Conduit Interior and Vent Pipe for Conduit Interior: Vent and drainage openings were plugged at both ends of site #5. The vent and drain openings in the crawl space were observed by team members. Information about the end plate in the manhole at the other end was provided by base personnel, who noted that both openings had been plugged since system installation. The source of water in the conduit was unknown.

Conduit.

1. Conduit Temperature: The temperature on the surface of the conduit was 205°F.

2. Conduit Coating: A film of coating was observed on the top quarter of the conduit.

3. Exterior Surface of Conduit: The plate cut out of the steam conduit contained a rust spot, which had consumed about 25 percent of the pipe's wall thickness.

4. Interior Surface of Conduit: There was minor corrosion on the plate cut from the conduit.

5. Inside of Exposed Conduit: About 3 in. of water were found in the bottom of the conduit.

6. Other Feature, Pipe Support: The pipe support in the area of the inspection opening was in good condition.

Thermal Insulation. The insulation was soggy, but showed little physical deterioration. However, the white sediment in the water which drained from the conduit in the crawl space indicated that some insulation had deteriorated due to contact with water.

Heat-Carrying Pipe. Heavy steaming made the exterior surface of the steam line hard to examine. However, a 2-in. square area was exposed and appeared to be in good condition.

Summary

The findings of the field inspection at Fort Polk, LA, are summarized in Table G1.

Table G1

Summary of Heat Distribution Systems at Fort Polk, LA

Site	System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial (ft)	Soil Resistivity (ohm/cm^3)	pH	Condition*
1	C-1	A	6 6	Steam and condensate	8	4,200	4.9	D
2	C-1	A	6	Steam	4	8,000	5.0	C
3	C-1	A	6	Steam	10	7,000	5.7	C
4	C-1	A	6	Condensate	4	10,000	4.0	D
5	C-1	A	6	Steam	3	7,000	4.8	C

* Definitions:

C = not efficient--repair
D = not efficient--replace

APPENDIX H:

SITE INSPECTION DATA AT LOCATION 7, GRAND FORKS AFB, NORTH DAKOTA

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Introduction

This location uses eight different heat distribution systems. The system consists of about 28 percent above-ground piping; 30 percent underground piping in insulating concrete (site 2); 30 percent shallow concrete surface trench (S-U systems at sites 6, 11, 11B; a cast-in-place concrete crawl-through system (at site 12); 10 percent prefabricated steel conduit system (C-1 system at site 1, C-2 system at sites 7, 8); 1 percent fiberglass reinforced plastic (FRP) conduit (site 9); 1 percent underground pipe in insulating powder (sites 4, 4B, 5, 10); and a section of buried shallow concrete trench (B-S at site 3).

The heat distribution system transports HTHW from the central heating plant. The capacity of the HTHW generators is 178 million Btu/hr. The system operates continuously, and the temperature of the hot water ranges from 350 to 400°F, with pressure from 240 to 280 psig.
The system was on during inspection.

The average yearly rainfall in this area is 19.3 in., and the maximum monthly rainfall is 3.6 in.

General Observations and Comments From System Users

The high temperature keeps the HTHW pipes on both the service and return lines free from external corrosion by keeping moisture out of the pipe area. However, water scale formed on pipes where standing ground water was present.

The record of make-up water in the central heating plant is less than 1 percent.

The storm drain system was used to drain the heat distribution systems. Most of the manholes were dry, and the components were in good condition.

The above-ground piping is insulated with calcium silicate and covered with an aluminum jacket. The pipe is about 2 to 3 ft above grade, except for overpasses over roads and sidewalks, etc., where it is 15 to 20 ft above grade. From a maintenance standpoint, the above-ground piping is the most trouble-free area of the heat distribution systems. The visual aspect of the above-ground piping is the most significant problem with this system.

Site Observation

Site #1

Location. This site was in an area surrounded by Buildings 603, 605, and 607.

Date of Inspection. 11 May 1982.

Date of Conduit Installation. 1958.

Age of Conduit. 24 years.

System Description and Known History. This system was installed prior to the Tri-Service Specification and had two 18-in. corrugated galvanized steel conduits. One contained a 10-in. HTHW supply line, and the other contained a 10-in. HTHW return line. The conduit sections were welded together on steel collars and the joints coated with a protective sealant in the field. Insulation was a 1.5-in. thick layer of mineral wool with fabric covering. There was a minimum of 1 in. annular air space between the insulation and the conduit. No cathodic protection was provided at initial installation, but sacrificial anodes were added after about 13 years of operation. The system had been uncovered for at least a week prior to the inspection for replacement.

This system had experienced failures at the joints, where many steel collars had rusted away. A replacement construction plan was scheduled in which a section in the joint area would be cut off and replaced with another steel split ring. The ring would be welded in place.

Excavation Characteristics.

1. Soil Condition: The terrain was flat. The soil was heavy and black, with a consistency tending toward clay. Percolation characteristics were not known. The soil was very damp at the conduit level, and water was observed about 1 ft below the conduit. Because of the proximity of the water table to the bottom of the conduit, the site was considered Class A. The soil resistivity was 27,000 ohm/cm^3, and the pH was 5.56. The soil was mildly corrosive.

2. Evidence of Excessive Heat Loss: Steaming was observed from areas near the conduit joints and from the conduit and manhole vents.

3. Depth of Burial: 7.5 ft.

Adjacent Manholes.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 9 ft by 9 ft by 10 ft deep. The invert of the conduit was 8 ft below grade.

(b) Piping and Components: The insulation around the pipe had deteriorated. Some of it had been worn away by individuals stepping on the pipes to get into the manhole.

(c) Flooding and Drainage: Water was observed in the manhole up to the bottom of the heat-carrying line. The storm drain was plugged.

(d) Ventilation: Two gooseneck vents were available; however, one vent was submersed in water.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: The coating had deteriorated, and the end plate was rusted.

(c) Drainage Opening for Conduit Interior: The drain was open.

(d) Vent Pipe for Conduit Interior: Steam was rising from two gooseneck vents, which indicated that flooding of the conduit had occurred.

Conduit.

1. Conduit Coating: The corrugated galvanized steel conduit was coated with a mastic material. The coating had softened and flowed from the top of the conduit to the invert area. There was no reinforcing mesh or felt. Most of the joints were bare and rusted.

2. Exterior Surface of Conduit: There were corrosion holes near the joint area; however, base personnel stated that the other sections were in good condition.

3. Inside of Corroded Area: Soil and water were found in the conduit.

4. Other Features, Field Joint: The steel joint collars were bare and rusted.

Thermal Insulation. The mineral wool insulation was powdery, indicating that some water had boiled within the conduit. However, the insulation was physically intact and, if kept dry, should work effectively for many years.

Heat-Carrying Pipes. The heat-carrying pipes were generally in good condition, with only light rusting and minor pitting.

Site #2

Location. Southwest of Building 418.

Date of Inspection. 11 May 1982.

Date of System Installation. 1956.

Age of System. 26 years.

System Description and Known History. The system contained two 12-in. HTHW lines in an insulated concrete system. Two excavations were made on the same section of line about 100 yd apart. The north excavation had been dug up previously. Most of the inspection focused on the south site, since it exposed the system as it had been constructed originally.

Excavation Characteristics.

1. Soil Condition: The terrain was flat. The soil was black and did not have the clay consistency of other sites on the base. It was extremely damp around the conduit, and water had accumulated above the line. This site was designated as a Class A site. Insulating concrete was recommended for installation only in dry areas (NAS-NRC publication 1412). The soil resistivity was 13,000 ohm/cm^3, and the pH was 6.7.

2. Evidence of Excessive Heat Loss: No grass was growing along the line of the system, indicating that excessive heat loss had occurred. Steaming occurred at some areas along the line and was observed from the site during the excavation and continuing throughout the inspection. At the north site, the ground temperature was 81°F above the conduit, 170°F at about 1.5 ft below grade, and 183°F at about 2 ft below grade. At the south inspection site, the ground temperature was 108°F at 10 in. from the pipe at the insulating concrete/earth interface, and 138°F at 4 in. above the pipe. The ambient ground temperature away from the system was 51°F. The HTHW supply was about 320°F, and the return was about 295°F.

3. Depth of Burial: 4 ft.

Adjacent Manhole. An insulating concrete system penetrating the manhole near site 4 was inspected. The flashing had been damaged, which would allow water to enter the system if the manhole became flooded.

Conduit or Casing Material. The bituminous waterproofing membrane had deteriorated. It was granular and contained rocks, which allowed water to enter the system.

Thermal Insulation.

1. Insulation Material: The outer layer of the 10-in. thick mix of concrete envelope and insulation covering the heating pipes was wet. However, about 4 in. from the pipe, the insulation was dry from the heat of the pipes. Soil was also found in the insulation. A laboratory test showed that the moisture content of the insulation near the pipe was only 2 percent.

2. Strengthening Wire Mesh: The steel wire mesh had rusted badly, with some of it rusting away completely.

Heat-Carrying Pipe. Corrosion was observed on the pipes, and one corrosion pit was observed on the exterior of the supply pipe.

Site #3

Location. Between Building 411 and manhole 405.

Date of Inspection. 11 May 1982.

Date of Trench Installation. 1978.

Age of Trench. 4 years.

System Description and Known History. Two 1.5-in. high-temperature water lines were contained in a buried concrete trench having a removable top slab. The interior of the concrete trench was about 24 in. wide and 18 in. deep. The trench wall thickness was about 5 in., and its concrete top slabs were 5 in. thick, 34 in. wide, and 81 in. long. A gap of about 1 in. between the top slabs was filled with an asphalt compound. Between the top of the trench walls and the top slabs was a neoprene-type material about 3/4 in. thick. Piping was suspended from a 5-in. by 1.25-in. by 0.25-in.-thick steel channel installed across the top of the trench just below the top slab. At the point of suspension, the insulated piping was covered with galvanized sheet metal. Insulation consisted of 1 in. of fiberglass, except at the points of pipe suspension where foam glass insulation was used. The insulation was covered with a 40-lb felt wrap wired on with stainless steel wires on 18-in. centers.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil was a dark loam. The soil resistivity was 21,000 ohm/cm^3, and the pH was 7.

2. Depth of Burial: The top of the concrete trench was about 2.5 ft below grade. The cover was lifted with a sling attached to the backhoe.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 8 ft by 10 ft by 9 ft deep.

(b) Flooding and Drainage: The manhole contained 1 in. of water. The floor drain to the storm sewer system appeared to be open, and a waterline was evident at the 2-ft level.

2. System Penetration: The manhole was receiving no water from either the tunnel or the tunnel subdrain. However, one month earlier during the presurvey, water was observed coming from both the tunnel and subdrain.

Conduit or Trench.

1. Concrete Portion: The surface temperature of the top slab was 75°F. The trench was not waterproofed, but the concrete portion was in excellent condition.

2. Joint Area: The top slab did not have slip lap joints.

3. Inside of Exposed Area: There was about 0.5 in. of muddy water on the trench bottom. The trench was dry at the manhole, which indicated that the slope to the manhole varied. No watermarks were observed on the trench wall.

4. Other Features, Channel, Bolt, Nuts, U-Bolt Hanger: Mud and rust spots were found on the channel iron, and the steel bolt and nut and the edge of the thermal expansion slot were corroded. The steel hanger and pipe clamp that were touching the galvanized shield sheet had also corroded.

Thermal Insulation.

1. Insulation Material: The felt wrap had separated from the insulation at the fiberglass/foam glass interface.

2. Surface Temperature of Insulation: The temperature of the insulation was 110°F on the 330°F supply line, and 99°F on the 290°F return line.

Heat-Carrying Pipes. The heat-carrying pipes were in excellent condition.

Site #4A

Location. Southeast end of Building 213.

Date of Inspection. 11 May 1982.

Date of Insulating Powder System* Installation. 1972

Age of System. 10 years.

System Description and Known History. The excavation site was near a 1977 investigation site on the same system, in which surface water was found to be entering the system through the interface of the valve riser and insulating powder because no sealant had been applied. The current system was installed in 1972 to replace a 7-year-old prefabricated conduit. The leaking conduit was cut and spread open on the top. The insulation was removed and insulating powder poured around the heat-carrying pipes. Plastic sheets were then laid on top of the powder and the trench was backfilled. Both the 2-in. HTHW supply and the 1.5-in. return lines were in one conduit.

*Insulating powders coated with stearic acid.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil was a permeable dark loam saturated with water. The water table appeared to be at the same depth as the conduit. The soil resistivity was 13,000 ohm/cm^3, and the pH was 6.5.

2. Evidence of Excessive Heat Loss: Sparse grass growth above the system indicated that excessive heat loss had occurred. Steaming occurred when the ground was excavated above the system. The soil temperature was 120°F at 1 ft above the conduit. On 12 May 1982, a "geyser" was created by water which permeated the insulating powder. The soil temperature was at 160°F at 1 ft from the conduit.

3. Depth of Burial: 8 ft.

4. Backfill: Improper backfill techniques resulted in soil entering the system. Rocks were also found. Very little insulating powder was found in some areas.

Adjacent Manhole. The manhole was the same as the one described for site #4B.

Conduit.

1. Insulating Powder Enclosure: The conduit casing was heavily corroded. The temperature on the conduit was 142°F.

2. Plastic cover: The plastic cover was deteriorated and allowed ground water and soil intrusion.

3. Insulating Powder Settlement: Compression settlement of about 1 to 1.5 in. below the edge of the opened casing was observed. This resulted in an insufficient protective top layer.

4. Sealant: No sealant was applied between the insulating powder and the conduit, so a water pocket was formed as a result of capillary action.

Insulating Powder.

1. Insulation Temperature: The temperature near the pipe was 182°F, which was above the melting point (158°F) of the stearic acid coating on the calcium carbonate powder.

2. Materials: The insulating powder at the outer layer was in good condition. However, near the pipe, the powder had turned beige and brownish and had become cakey. It was muddy near the bottom of the conduit, and the moisture content of the mud was found to be 24 percent; chemical analysis of the insulating powder indicated that the major constituent was still calcium carbonate.

Heat-Carrying Pipes. No corrosion was observed on the heat-carrying pipes. The pH of the water that entered the system shortly after the observation window was cut was found to be 8.5, as opposed to 6.5 for the ground water outside the conduit. The difference in pH readings resulted from the dissolution of bare calcium carbonate powder, which made the water in the conduit alkaline.

Site #4B

Location. West of Building 213.

Date of Inspection. 11 May 1982.

Date of Insulating Powder System Installation. 1972.

Age of System. 10 years.

System Description and Known History. The insulating powder system was installed in 1972 to replace a 7-year-old prefabricated conduit system. The leaking conduit was cut and spread open on top. The insulation was removed, and the insulating powder was poured around the heat-carrying pipes. Plastic sheets were then laid on top of the powder and conduit before backfilling. Both the 2-in. HTHW supply and the 1.5-in. return line were in one conduit. The pipe temperatures taken at the manhole were 320°F for the supply line and 243°F for the return line.

The excavation was next to the thermal expansion anchor lock beside manhole 210 at the end of the line. This site was excavated to determine why steam was escaping from a vent pipe attached to the end plate of the old conduit-type system.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil was a permeable dark loam, which was saturated with water. The soil resistivity was 13,000 ohm/cm^3, and the pH was 5.6.

2. Evidence of Excessive Heat Loss: There were only small patches of grass growing above the system, which indicated heavy system heat loss. The soil surface temperature was 74°F above the system and 52°F away from the system. The ambient air temperature was 62°F, and the insulation temperature was 160°F underneath the heating pipe.

3. Depth of Burial: 5.5 ft.

4. Backfill: Improper backfill techniques caused soil to enter the system.

Adjacent Manhole.

1. Manhole Condition: The concrete manhole was flooded.

2. System Penetration: A steaming vent pipe indicated that the conduit was flooded.

Conduit.

1. Insulating Powder Enclosure: The conduit casing was heavily corroded.

2. Plastic Cover: The plastic cover was deteriorated, allowing ground water and soil intrusion.

3. Insulating Powder Settlement: Compression settlement resulted in an insufficient protective top layer.

4. Sealant: No sealant of any kind was applied between the insulating powder and foreign surfaces such as concrete wall, conduit, or heat pipes. Water entered into the system due to capillary action.

Insulating Powder Condition.

1. Insulation Temperature: The temperature was 160°F underneath the heating pipe and the protexulate cover.

2. Materials Condition: The insulating powder cover was in good condition at the outermost layer, but was beige and cakey at about 2 in. from the heat pipe. Rock-like scale was observed on the heat pipe, and chiseling and hammering were required to expose the pipe. Differential Thermal Analysis (DTA) of the scale formation indicated that it contained calcium carbonate. Mud with a moisture content of 28 percent was found in the bottom of the inner conduit.

Heat-Carrying Pipes. The exposed pipes were found to be in good condition; this probably resulted from the alkaline environment.

Site #5

Location. South of Building 223.

Date of Inspection: 12 May 1982.

Date of System Installation. 1971.

Age of System. 11 years.

System Description and Known History: Site 5 was selected because it used insulating powder and had new 1.5-in. diameter HTHW supply and return piping. The piping was installed according to the recommendations of the manufacturer of the insulating powder. The system used a wood, rectangular trough 18 in. wide and 12 in. deep to hold the powder in place. An oversized plastic sheet was laid on the trough bottom and sides. About 5 in. of powder were placed on the bottom of the trough; the pipes were then laid onto the insulating powder, maintaining about 4 in. between the pipe edge and the trough sidewall and about 3 in. between the two pipes. Six inches of powder were poured over the pipes. The plastic sheet was folded over the powder, and a layer of sand was poured over the plastic. The manufacturer stated that the insulating powder was essentially incompressible in the range of earth cover used at the site. The HTHW supply pipe temperature was measured at 280°F, and the HTHW return was measured at 102°F. These temperatures were thought to be lower than normal and caused by a low demand for heating in Building 223.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil was a permeable heavy, dark loam. The soil was only slightly damp around the system, and no indication of a high water table was observed. The soil resistivity was 10,000 ohm/cm^3, and the pH was 5.6. The soil temperature was 52°F away from the system and 60°F directly above the system.

2. Evidence of Excessive Heat Loss: None was observed.

3. Depth of Burial: 18 in.

Manhole. No data were obtained.

Conduit.

1. Insulating Powder Condition: The wood side forms were in good condition.

2. Plastic Cover: The plastic cover was in good condition.

3. Insulating Powder Settlement: Compression settlement was observed to be about 2 to 3 in.

Insulating Powder.

1. Insulation Temperature: The temperature was 92°F at about 6 in. from the supply pipe.

2. Material Condition: Most of the powder remained white, but was observed to be slightly beige and cakey near the pipe. A laboratory DTA test on the cakey scales indicated that the scales were composed of calcium carbonate and organic material.

Heat-Carrying Pipes. Both carrier pipes were in excellent condition and exhibited no signs of external corrosion.

Site #6

Location. Between Buildings 212 and 215.

Date of Inspection. 12 May 1982 (following a presurvey on 8 April 1982).

Date of Trench Installation. 1979.

Age of Trench. 3 years.

System Description and Known History. This shallow trench system was designed and installed by the base operations and maintenance personnel. This site was selected because the tunnel was known to be draining improperly. During the presurvey, steaming was observed from the trench when the top slab was lifted. The trench was found to be full of hot water at the heat pipe lines, and the water was gushing along the pipe wall in the mechanical room in the basement of Building 212. By 12 May, the standing water had drained away,, and the tunnel drainage system was operating normally. The cause of the standing water was found to be a frozen drain line. The drain line was routed to a nearby area drain; however, since the tunnel was very shallow, the drain line was only about 4 ft deep. At this site, the frost line was 7 ft below grade, so the drain line froze. Base personnel planned to reroute this drain line so it would not freeze in the future.

This system was similar to the standard S-U system. The shallow surface trench contained two 1.5-in. HTHW lines insulated with 1-in. fiberglass wrapped in 40-lb asphalt-saturated felt ties with stainless steel wires. At the point of suspension, the foam glass-insulated piping was covered with galvanized sheet metal. The piping was suspended with a U-bolt hanger under a 5-in. by 1.5-in. by 1/4-in. thick steel channel across the top of the trench.

Interior dimensions of the concrete trench were about 20 in. wide by 16 in. deep. The trench wall was about 5 in. thick. The trench's concrete tops were about 5 in. thick, 30 in. wide, and about 6 ft long. A neoprene pad (1/4 in. thick) was used as sealant for waterproofing between the top slab and the side wall. Neoprene foam rods between adjacent top slabs were topped with Vulkem polyurethane sealant. The surface temperature was 301°F at the supply line and 282°F at the return line.

Excavation Characteristics.

1. Soil Condition: The site was located on a low point in the area. The soil was permeable dark loam. No water table was observed.

2. Evidence of Excessive Heat Loss: Heavy steaming was observed during the 8 April 1982 presurvey inspection.

Adjacent Building Entry: During the presurvey inspection, water was found gushing into a mechanical room in the Building 212 basement. It then drained through the floor drain.

Conduit or Trench.

1. Concrete Portion: The concrete portion was in excellent condition.

2. Joint Area: Joint materials were in excellent condition.

3. Inside of Exposed Area: On 12 May, there was still about 0.5 in. of muddy water lying on the trench bottom. A watermark was visible near the heating pipes.

4. Other Features: The U-bolt hanger and channel were mildly corroded.

Thermal Insulation. The fiberglass insulation appeared to be intact; however, the portion that was in the boiling water disintegrated when touched. The foam glass pipe support insert retained its properties and appeared to have sustained no damage. The 40-lb felt pipe wrap was almost SOI completely deteriorated on the bottom of the pipe where it had been lying in boiling water.

Heat-Carrying Pipe. As an apparent result of prolonged (probably in excess of 1 month) boiling in ground water, a hard scale was deposited on the pipe surface.

Site #7

Location. Between Buildings 118 and 124.

Date of Inspection. 12 May 1982 (presurvey on 8 April 1982).

Date of Conduit Installation. 1967.

Age of Conduit. 15 years.

System Description and Known History. This site was selected because a gooseneck vent at the adjacent manhole (#102) was observed to be steaming during the presurvey. The gooseneck vent terminating above the manhole had been replaced before the inspection with a conduit vent that had a valve terminating in the manhole. The vent was still steaming at the time of the investigation.

The 18-in. steel conduit contained two 3-in. HTHW lines. These pipes were laid one over the other. They were insulated with a 1.5-in. layer of calcium silicate and had a minimum of 1 in. annular air space. A cathodic protection system was installed and was operational.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil was heavy and dark with a clay-like consistency. The soil was wet, but no water table was observed. The soil resistivity was 17,000 ohm/cm^3, and the pH was 5.8.

2. Evidence of Excessive Heat Loss: There was no grass growing above the line. Steaming was observed when the opening was cut into the conduit. The ambient temperature was 53°F, and the earth surface temperature was 69°F above the conduit and 58°F away from the conduit.

3. Depth of Burial: 5 ft.

4. Backfill: The conduit was surrounded by 6 to 12 in. of sand.

Adjacent Manhole (MH102) and Building Entry (Basement of Chapel).

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 9 ft by 9 ft by 7 ft deep. The invert of the conduit was 5 ft below grade.

(b) Piping and Components: The piping and components were in good condition.

(c) Flooding and Drainage: There was a waterline near the 3-in. level.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: The coating was deteriorated, and the end plate area was rusted.

(c) Drainage Opening for Conduit Interior: The conduit end plate in the chapel basement was rotated by 90 degrees and therefore improperly installed. A drain faucet was dripping water continuously. Efforts to remove blockage in the conduit drain were unsuccessful.

(d) Vent Pipe for Conduit Interior: The pipe ended inside manhole #102. The vent opening was rotated by 90 degrees (i.e., it was located at the side of end plate rather than the top). It was also plugged.

(e) Seal Around Conduit: A poor seal allowed rusty water to pass through the conduit.

Conduit.

1. Conduit Temperature: The temperature was 190°F on top of the conduit casing at the excavation site and 213°F on top of the conduit at the entrance through the building wall.

2. Conduit Coating: The conduit coating was in very good condition.

3. Exterior Surface of Conduit: Pitting which consumed about 10 to 15 percent of the conduit wall thickness was observed.

4. Interior Surface of Conduit: Corrosion was observed.

5. Inside of Exposed Conduit: There were 1.5 in. of water in the bottom of the conduit.

Thermal Insulation.

1. Insulation Material: The insulation was in excellent condition on the top pipe. However, on the bottom pipe, it was wet and soggy and showed some deterioration.

2. Surface Temperature of Insulation: The temperature was 191°F on the top pipe.

Heat-Carrying Pipe. Heavy steaming prevented inspection.

Site #8

Location. Northwest side of Building 120.

Date of Inspection. 12 May 1982.

Date of Conduit Installation. 1976.

Age of Conduit. 6 years.

System Description and Known History. The 14-in. steel conduit contained two 1.5-in. HTHW lines insulated in 1.5-in. calcium silicate, with a 1-in. minimum air space. The supply line was located above the return line. The temperature of the supply line was 280°F, and the temperature of the return line was 132°F.

Excavation Characteristics.

1. Soil Condition: The site area was level, and the soil was dark with a clay-like consistency. The soil was moist at the conduit level, but no water table was observed. The soil resistivity was 4500 ohm/cm^3, and the pH was 5.5.

2. Depth of Burial: 4 ft.

Adjacent Building Entry. The entry of the system to the building was not built according to standard practices.

1. System Penetration: There was no way to drain or pressure-test the system.

2. Vent Pipe for Conduit Interior: The vent pipe was improperly installed, and steam was rising from it.

Conduit.

1. Conduit Temperature: The temperature was 112°F on the steel conduit. The normal ground temperature was 54°F and was 62°F directly above the conduit.

2. Conduit Coating: The conduit coating was thinner on the top than on the bottom; however, it was still in good condition.

3. Exterior Surface of Conduit: The conduit's exterior surface was in excellent condition.

4. Interior of Casing: Moderate corrosion was observed.

5. Inside of Exposed Conduit: There was about 1 in. of water in the bottom of the conduit.

Thermal Insulation.

1. Insulation Material: The insulation was reasonably dry on the top of the pipe, but it was wet, soggy, and deteriorated on the extreme bottom. The insulation blocks were loose and had fallen to the bottom of the conduit.

2. Tie-Strap: The tie-strap had rusted and was dangling in some areas.

3. Surface Temperature of Insulation: The temperature was 100°F on the top pipe and 90°F on the bottom pipe.

Heat-Carrying Pipe. The heat-carrying pipes were in good condition.

Site #9

Location. Northwest of Building 105.

Date of Inspection. 12 May 1982.

Date of Conduit Installation. 1973.

Age of Conduit. 9 years.

System Description and Known History. The 14-in. filament spiral-wound fiberglass-reinforced-plastic (FRP) conduit contained two HTHW pipes, one laid over the other. The two 2-in. HTHW pipes were insulated with calcium silicate, with a 1-in. minimum annular air space.

No inspection opening was cut in this conduit because the base did not have a standard repair technique for the plastic shell. However, two holes, 3 to 4 sq in. in diameter, in the conduit shell from a previous excavation allowed observations to be made.

Excavation Characteristics.

1. Soil Condition: The terrain was flat, and the soil was black with a clay-like consistency.

2. Evidence of Excessive Heat Loss: None was observed.

3. Depth of Burial: 3 ft.

4. Backfill: There were 6 to 12 in. of sand surrounding the conduit.

Adjacent Manhole or Building Entry, System Penetration.

1. End Plate: One end of the conduit ended in manhole 101, and the other ended in the mechanical room of the Base Exchange. The conduit entered the floor vertically by means of a movable end plate that was neither pressure-testable nor drainable. The end plate in manhole 101 was made of steel and coated with pre-cured epoxy resin. The surface temperature on the epoxy coating was 167°F.

2. Waterproof Casing Coating: The coatings on the end plate and the pipe penetration were blistered.

3. Drainage Opening for Conduit Interior: In manhole 101, the drain was rusted tight and could not be opened.

4. Vent Pipe for Conduit Interior: There was no vent pipe in manhole 101.

5. Seal Around Conduit: The seal around the conduit was poor.

Conduit.

1. Exterior Surface of Conduit: Holes and shredding fibers were observed on the conduit. The conduit deformed under the weight of backfill soil and became oblong.

2. Inside of Exposed Conduit: Fine sand and water were standing on the conduit invert and appeared to be several inches deep.

Thermal Insulation.

1. Insulation Material: There was evidence that the lower portion of the insulation on the lower pipe in the conduit had deteriorated.

2. Surface Temperature of Insulation: The temperature was 86°F on the insulation of the top pipe and 365°F on the pipe surface. On the lower pipe, the temperature was 99°F on the insulation and 324°F on the pipe.

Heat-Carrying Pipe. The heat-carrying pipe was not inspected.

Sites #10A, 10B

Location. Site 10A was located at the northwest corner of Building 231, south of manhole 205. Site 10B was located southwest of Building 229, north of manhole 205.

Date of Inspection. 13 May 1982 (10A), 8 April 1982 (10B).

Date of Trench Installation. 1977.

Age of Trench. 5 years.

System Description and Known History. Two sites were inspected, one on each side of manhole 205. The sites contained the shallow concrete surface trench systems (S-U). The top cover slabs of the trenches served as a sidewalk. This system contained two 6-in.-diameter pipes (HTHW supply and return) which had 2 in. of fiberglass insulation and an all-purpose jacket. The insulation was wrapped with 40-lb felt and secured with stainless steel wires. The pipes were supported with a painted steel channel and were attached with U-bolts to the channel section. A foam glass insert and galvanized metal shield were between the U-bolt and each HTHW pipe.

The inside of the trench was 36 in. wide and 24 in. deep, and its walls were about 5 in. thick. The concrete top slabs were 5 in. thick, 46 in. wide, and 96 in. long. A neoprene pad (3/8 in. thick) was used between the top slabs and the side wall as a sealant for waterproofing. A neoprene foam rod topped with Vulkem polyurethane sealant was used between the top slabs.

The temperature was 324°F on the surface of the HTHW supply pipe and 295°F on the surface of the HTHW return pipe.

A 4-in. drain was installed about 6 in. below the centerline of the trench.

Site Characteristics.

1. Soil Condition: The terrain was level, and the soil was a dark loam. No water table was observed.

2. Evidence of Excessive Heat Loss: None was observed.

Adjacent Manhole (Manholes 205 and 204).

1. Manhole Condition:

(a) Arrangement: The dimensions of the manhole were 9 ft by 9 ft by 8 ft deep.

(b) Flooding and Drainage: No watermarks were observed on the manhole walls. A small amount of water was flowing from the conduit subdrain to the floor drain in the manhole; this was probably the result of a recent heavy rain.

Trench.

1. Concrete Portion: The concrete trench, the tops, the foam plastic between the slabs, and the neoprene seals between the tops and the trench walls all appeared to be in excellent condition. There appeared to be no settling of the trench and no cracking or spalling of the concrete.

2. Joint Area: The neoprene seal pads and rods worked reasonably well, except at overlapping areas where water-drip stains were observed.

3. Inside of Exposed Area: Some water had entered the trench. A film of water was observed on the tunnel floor in some areas, and about 1/4 in. of water was observed in the thermal expansion loop area. There were no horizontal watermarks on the trench walls, but there were marks on the walls caused by the intrusion of water into cracks between the tops and trench side walls.

Thermal Insulation.

1. Insulation Materials: Insulation materials were in excellent condition.

2. Tie-Strap: The tie-strap was in excellent condition.

3. Surface Temperature of Insulation: The temperature on the felt wrap was 87°F on the supply line, 75°F on the return line, and 68°F on top of the concrete slab. The ground temperature was 56°F.

4. Other Features: The U-bolt threads, the nut, and the steel channel had only slight corrosion.

Heat-Carrying Pipes. No data were obtained.

Summary

Table H1 summarizes the results of the field investigations at Grand Forks AFB, ND, in April and May of 1982.

Table H1

Summary of Heat Distribution Systems at Grand Forks AFB, ND

Site	Type of System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial (ft)	Soil Resistivity ohm/cm^3	pH	Condition*
1	C-1	A	24	2HTHW	7.5	27,000	5.56	C/D
2	Z	A	26	2HTHW	4	13,000	6.7	D
3	B-S	A	4	2HTHW	3	21,000	7	B
4	P	A	10	2HTHW	8	13,000	6.5	D
4B	P	A	10	2HTHW	5.5	13,000	5.6	D
5	P	B	11	2HTHW	1.5	10,000	5.6	B/C
6	S-U	A	3	2HTHW	--	--	--	C
7	C-2	A	15	2HTHW	5	17,000	5.8	C/D
8	C-2	A	6	2HTHW	4	4,500	5.5	D
9	F-C	A	9	2HTHW	3	--	--	D
10A	S-U	A	5	2HTHW	--	--	--	A
10B	S-U	A	5	2HTHW	--	--	--	A

*Definitions:

A = efficient
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace

APPENDIX I:

SITE INSPECTION DATA AT LOCATION 8, PENSACOLA NAVAL AIR STATION, FLORIDA

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Introduction

This investigation involved the excavating of underground conduits at six sites (sites 1, 2, 3, 4, 5, and 8). Since the condensate return lines were all made of fiberglass-reinforced plastic (FRP), the steam-carrying lines were inspected. Investigating the other two sites required removing the covers. One was a deep manhole (site 7), and the other was a shallow-surface tunnel system with a prefabricated conduit containing the heat-carrying pipes (site 6).

The rainfall at Pensacola had reached an annual high of 90.41 in. The 40-year average was 60.1 in. per year, and the highest monthly average recorded was 20.36 in. The ground water elevation in the area was about 3 ft below grade. The combination of a high water table and high rainfall dictated that this site be designated as Class A.

A special dewatering system had to be put in place for the excavation. This system consisted of 8 to 10 well-head sand points driven into the earth to an elevation lower than the intended excavation. A special diesel-powered vacuum pump was hooked to the sand points and a 6-in. pipe header. The dewatering unit was equipped with a vacuum-water separator and a centrifugal water pump. The outflow from this unit was a 6-in. pipe which was half to three-quarters full during the pumping.

All the inspection sites except site 8 were excavated, and openings were cut into the conduits about a week before the inspection team arrived. Storm-water flooded some of the sites and forced sand into the open conduits. The temperature profiles were not recorded. Base personnel cut 3-ft sections out of the conduit for the inspection. These openings were much larger than those used at other locations, so more insulation and larger heat-carrying pipe areas were exposed. Thus, team members were able to observe deficiencies that could have been overlooked if only small openings had been cut.

General Observations and Comments From System Users

Ground water covered the conduits in all sites investigated except site 6, which was a shallow concrete surface trench. The soil was typically a white, fine sand with good percolation properties. The soil resistivity varied from 225,000 ohm/cm^3 at 2.5 ft below grade to 35,000 ohm/cm^3 at 10 ft below grade. The current criteria do not require cathodic protection.

Although relatively new, the conduits in sites 1 and 5 have been abandoned and replaced. The steam pressure was off for the summer at sites 3 and 6. This was detrimental to the system because the steam-operated manhole sump pumps (ejectors) would not function and allowed the manholes to fill with water. This, plus the lack of correct routine maintenance within the manhole, was judged to be one of the prime causes of conduit failures.

Site Observation

Site #1

Location. West side of manhole 148 south of Building 654.

Date of Inspection. 8 June 1982.

Date of Conduit Installation. 1974.

Age of System. The system was abandoned in 1977.

System Description and Known History. The conduit shell was about 18 in. in diameter and contained an 8-in. steam pipe, 2.5 in. of calcium silicate insulation, and an annular air space larger than 1 in. The condensate return line appeared to be 4 in. in diameter. The return line was wrapped in steel and not in a conduit. No cathodic protection was installed.

The line, which ran under a paved road, was abandoned in 1977 when a leak occurred. Base personnel had thought that the cost of the excavations that might be necessary to locate the leak could exceed the cost of replacing the system. After the inspection, team members concluded that water had entered the air cavity before the system was abandoned; however, the source of the water could not be determined. Since the steam line was not active, no steam pressures or temperatures were recorded. The principal cause of failure was not established.

Excavation Characteristics.

1. Soil Condition: The site had been excavated the week before the inspection team arrived. The ground water level was ordinarily above the system; however, for this investigation, ground water was pumped out of the soil. The soil resistivity was 225,000 ohm/cm^3 at 2.5 ft, 140,000 ohm/cm^3 at 5 ft, and 34,000 ohm/cm^3 at 10 ft below grade.

Since the water table is normally about 3 ft below grade, the site was considered Class A. A laboratory analysis revealed that the water's pH was 6.85 and its chloride content negligible.

2. Depth of Burial: 7 ft.

Adjacent Manhole. 10 ft from excavation.

1. Manhole Condition:

(a) Arrangement: The concrete manhole was 9 ft by 9 ft by 9 ft deep. The invert of the conduit was 8 ft below grade.

(b) Accessibility: There was no ladder installed.

(c) Piping and Components: No insulation was noted on the piping, and severe corrosion was evident.

(d) Flooding and Drainage: 8 in. of hot water were observed in the manhole, even though the area around it was being drained. No drain or sump pump was provided.

(e) Ventilation: Ventilation was provided by an 8-in. vent with a cap.

(f) Manhole Structure: A heavy asphaltic coating was observed on the manhole's exterior. The entire manhole was covered with a 1/4-in. plate in four quadrants.

2. System Penetration:

(a) End plate: No data were obtained.

(b) Waterproof Casing Coating: No coating was observed, and the plate was severely rusted.

(c) Drainage Opening for Conduit Interior: The drain was 6 in. from the bottom and was left open.

(d) Vent Pipe for Conduit Interior: The vent ended in the manhole.

Conduit.

1. Conduit Coating: The conduit coating was in good to excellent condition.

2. Exterior Surface of Conduit: Minor corrosion spots were observed.

3. Interior Surface of Conduit: Heavy corrosion was observed on the bottom of the casing where it appeared that about 4 in. of water may have stagnated.

Thermal Insulation. The insulation showed only some minor deterioration. However, there were some scattered signs of a reaction between the insulation and the heat-carrying pipes which had produced barnacle-like inclusions on the insulation surface and deep corrosion pits on the heat-carrying pipes.

Heat-Carrying Pipes. The exterior of the supply pipe was severely corroded and pitted on both the top and the bottom. Counterpart pits and reacted zones were also observed on the insulation.

Site #2

Location. North side of manhole 148, south of Building 654.

Date of Inspection. 8 June 1982.

Date of Conduit Installation. 1977.

Age of Conduit. 5 years.

System Description and Known History. The 18-in. diameter steel conduit contained an 8-in. steam line; the line was insulated in 2.75-in. calcium silicate blocks and contained a minimum of 1 in. annular air space. The 4-in., unwrapped, fiberglass-reinforced plasic (FRP) condensate return line ran along the side of the conduit. There was another 4-in. steam line in the same area which was insulated with 1-5/16 in. of foam glass and covered by an aluminum jacket with no air space. No cathodic protection was installed. The system operated continuously at a steam pressure of 150 psig.

Excavation Characteristics.

1. Soil Condition: The soil conditions were similar to those of site 1. The site had been excavated and the conduit opened about 1 week before the investigation. The soil resistivity was 225,000 ohm/cm^3 at 2.5 ft, 140,000 ohm/cm^3 at 5 ft, and 34,000 ohm/cm^3 at 10 ft. The site was designated as Class A.

2. Depth of Burial: 4 ft.

Adjacent Manhole. The manhole characteristics were the same as that of site 1, except that the invert of the conduit penetration was 4 ft below grade. The system penetration area into the manhole was not accessible for inspection.

Conduit.

1. Conduit Coating: The conduit coating was in good to excellent condition.

2. Exterior Surface of Conduit: The exterior surface of the conduit was in excellent condition; however, the aluminum jacket was severely pitted.

3. Interior Surface of Conduit: There was corrosion with some pitting on the interior surface of the conduit.

Thermal Insulation. The foam glass insulation was in very good condition. The calcium silicate insulation blocks were also in good condition, although some rust marks and eroded holes were observed on top of the insulation.

Heat-Carrying Pipes. All three pipes were in excellent condition.

Site #3

Location. Between manhole 72 and Building 3588, immediately east of the anchor block outside of manhole 72.

Date of Inspection. 8 June 1982.

Date of Conduit Installation. 1979.

Age of Conduit. 3 years.

System Description and Known History. The 16-in. steel conduit contained an 8-in. steam line insulated with 2.5-in. calcium silicate and a 1-in. minimum annular air space. The 2-in. uninsulated FRP condensate return line ran along the side of the conduit. No cathodic protection was installed. The steam line had been turned off for the summer, so no temperature measurements were recorded. Steam-powered ejector pumps that were installed into the manhole east of site 3 did not work during the system shutdown. Consequently, the manhole was flooded with water up to its top.

Excavation Characteristics.

1. Depth of Burial: 3 to 4 ft.

Adjacent Manholes. (Manholes 72 and 72A).

1. Manhole Condition:

(a) Arrangement: Manhole 72 was concrete with dimensions of 7 ft by 10 ft by 8 ft deep. Manhole 72A was about 6 ft in diameter.

(b) Accessibility: The construction of the entrance ladder made it dificult to enter the manhole.

(c) Piping and Components: The insulation was worn away, leaving only dangling tie-wires on rusted piping.

(d) Flooding and Drainage: The manhole was full of water to within about 1 ft of the top.

(e) Ventilation: Each manhole had two gooseneck vents.

(f) Manhole Structure: There was heavy asphaltic coating on the manhole exterior. The coating had cracked on manhole 72A.

2. System Penetration:

(a) End plate: No data were obtained.

(b) Waterproof Casing Coating: Most of the original coating had deteriorated, and both the gland seal and end plate were rusted.

(c) Drainage Opening: A brass drain plug was present.

(d) Vent Pipe for Conduit: The conduit was vented properly; however, installation of the vents was unusual. The vent pipe doubled back along the conduit after the end plate and then ran vertically to the outside of the manhole. Most of the vent pipe was cast in concrete, which may have been part of the conduit shell anchor.

(e) Seal Around Pipe: The gland seal was leaking. In addition, some nuts were missing or loose, which allowed water from the manhole to enter the conduit.

Conduit.

1. Conduit Coating: No evidence of deterioration was noted.

2. Exterior Surface of Conduit: No corrosion was observed.

3. Interior Surface of Conduit: The surface was covered with a heavy rust scale at the invert, indicating that there had been standing water inside the conduit.

Thermal Insulation. The insulation blocks were in good condition. However, the deep pits on the heat-carrying pipes indicated that they had reacted with the insulation.

Heat-Carrying Pipes. There were deep pits on the exterior of the supply pipe. The lower portion of the supply pipe had been covered by water.

Site #4

Location. Immediately north of manhole 72.

Date of Inspection. 8 June 1982.

Date of Conduit Installation. 1975.

Age of Conduit. 7 years.

System Description and Known History. The 18-in. steel conduit contained a 10-in. steam line insulated by 2.5-in. calcium silicate blocks and a 1-in. minimum of air space. The 4-in. FRP condensate return line was wrapped in an asphaltic material and buried beside the conduit. No cathodic protection was installed. The system operated continuously and was in service during the inspection, operating at a steam pressure of 150 psig.

Excavation Characteristics. The conduit was buried 4 to 5 ft below grade.

Adjacent Manhole. The characteristics of manhole 72 were described in the text for site 3.

Conduit.

1. Conduit Coating: No deterioration was observed; the coating was in excellent condition.

2. Exterior Surface of Conduit: No corrosion was observed; the conduit was in excellent condition.

3. Interior Surface of Conduit: Some corrosion was evident on the top half, and heavy corrosion was found on the bottom quarter.

Thermal Insulation. The insulation was in good physical condition except at locations touched by the pipe surface, where deep corrosion pits were observed.

Heat-Carrying Pipes.

1. Supply Pipe Exterior: Corrosion spots containing pits about 0.07 in. deep were observed. The corrosion was more severe on the sides and lower quadrant of the steam-carrying pipe.

2. Return Pipe Exterior: Minor deterioration of the wrapping on the condensate return line was noted.

Site #5

Location. The site was located between manholes 73 and 75, west of Building 3460.

Date of Inspection. 8 June 1982.

Date of Conduit Installation. 1976.

Age of System. The system was abandoned in 1981.

System Description and Known History. The 18-in. steel conduit contained an 8-in. steam pipe insulated in calcium silicate blocks and a 1-in. minimum annular air space. The section of the conduit removed for the inspection was an elbow section of an expansion loop.

Base maintenance personnel had dug up five separate sites along the line, but could not locate the leaks, so they abandoned this line and installed a new line above ground.

Excavation Characteristics. The system was buried 6 ft below grade.

Adjacent Manhole. No data were obtained.

Conduit.

1. Conduit Coating: The mastic on the exterior surface of the conduit had softened and dripped toward the invert of the conduit.

2. Exterior Surface of Conduit: General corrosion was evident on the top of the conduit where the coating had sloughed off.

3. Interior Surface of Conduit: The top portion was generally corroded; the bottom was corroded through in several spots.

4. Other Features, Weld at Thermal Expansion Loop: An inspection of the joint surface showed evidence of poor weld penetration and mismatch. Cracks had also developed at the welded joint.

Thermal Insulation. No data were obtained.

Heat-Carrying Pipes. Corrosion was observed on the heat-carrying pipes.

Site #6

Location. Near Building 607.

Date of Inspection. 9 June 1982.

Date of Conduit Installation. Concrete trench--1920; present conduit in trench--1955.

Age of Conduit. 27 years.

System Description and Known History. A 6-in. steam line and 2-in. condensate line in a steel casing were installed in an existing concrete trench 3 ft wide, 34 in. deep, with 6-in. thick walls. The conduit system was installed before the Tri-Service criteria became effective. The concrete top slabs were 3 ft wide, 4 in. thick, and 14 in. long. The lower surface of the concrete cover had an indentation which matched the tunnel wall top and a tapered section where the tunnel tops butted together. The tapered section, which formed a shallow "V" when two covers were butted together, was filled with portland cement to waterproof joints. The joints showed no signs of cracking at the time of the inspection. The conduit was supported in the trench with prefabricated concrete supports and could not be cut open, so no data were obtained about the system condition within the conduit.

The system was intermittent and was off during the inspection. Its operating pressure was 150 psig.

Excavation Characteristics. No excavation was done.

Adjacent Manhole 89.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 5 ft by 6 ft by 4 ft deep.

(b) Accessibility: The manholes were covered with four checkered-plate steel plates laid over a square crossframe. These removable tops were desirable for both safety and maintenance purposes.

(c) Piping and Components: Two valves were heavily corroded and leaking. The condensate line was heavily corroded, and both the insulation and felt wrapping were deteriorated. An aluminum jacket covered the steam line insulation.

(d) Flooding and Drainage: There were 14 in. of water in the bottom of the manhole. The steam ejector pump was not operational, since the system was off.

(e) Ventilation: None was observed.

(f) Manhole Structure: Spalling of the concrete interior manhole walls was observed.

2. System Penetration:

(a) End Plate: No data were obtained.

(b) Waterproof Casing Coating: The coating had worn away, and the end plates were heavily corroded.

(c) Drainage Opening for Conduit Interior: No drains were present.

(d) Vent Pipe for Conduit Interior: No vents were present.

Trench.

1. Concrete Portion: Some spalling was noted on the trench wall; otherwise, the 60-year-old trench was in very good condition.

2. Joint Area: The joint area was in very good condition.

3. Inside of Exposed Area: The tunnel drained to the manhole. About 0.5 in. of muddy water were on the trench floor.

4. Other Features: The steam line coating and the pipe appeared to be in very good condition.

Thermal Insulation. No data were obtained.

Heat-Carrying Pipe. No data were obtained.

Site #7

Location. Manhole 31 near Building 3568.

Date of Inspection. 9 June 1982.

Date of Installation. Not determined.

System Description and Known History. This examination of manhole 31 did not include an inspection of a conduit system. The primary purpose of the steam line was to service ships tied to the pier. The next manhole (#30) closer to pier 303 was full of boiling water.

Excavation Characteristics. No excavation was made at this site.

Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 8 ft by 8 ft by 10 ft deep.

(b) Piping and Components: The 10-in. steam line had no insulation. Other components were corroded.

(c) Flooding and Drainage: About 6 in. of water and fuel oil were in the bottom of the manhole. Maintenance personnel stated that the manhole had been flooded and filled with mud. No effective means of draining the manhole was available.

(d) Ventilation: One-half of the manhole cover was 1/4-in. plate; the other half was open grate.

2. System Penetration:

(a) End plate: No data were obtained.

(b) Drainage Opening for Conduit Interior: The drain plug was in place.

(c) Vent Pipe for Conduit Interior: No vent pipe was provided.

Site #8

Location. Between manhole 73 and Building 3460.

Date of Inspection. 9 June 1982.

Date of Conduit Installation. 1974.

Age of Conduit. 8 years.

System Description and Known History. The 12-in. steel conduit contained a 4-in. steam line insulated in 2-in. calcium silicate blocks and a 1-in. minimum air space. No cathodic protection was provided. The intermittent operating system was off during the inspection. The steam pressure during operation was 150 psig. An 8 in. by 14 in. inspection opening was cut into the conduit.

Excavation Characteristics. The water table was 3.5 ft below grade. The soil resistivity at 5 ft was 220,000 ohm/cm^3, and at 10 ft was 200,000 ohm/cm^3. The result of the ground water analysis in the laboratory showed that the pH was 7.05 with negligible chloride content.

Adjacent Manhole.

1. Manhole Condition:

(a) Arrangement: The dimensions of the concrete manhole were 5 ft by 6 ft by 8 ft deep. The invert of the conduit was 6 ft below grade.

(b) Piping and Components: General corrosion was observed.

(c) Flooding and Drainage: Mud was found in the bottom of the manhole. Minor leakage occurred at the condensate line penetration into the wall and at the vertical corners of the manhole. The steam ejector pump was in operation.

(d) Ventilation: Vents were capped and exited at the steel-plate covered half of the manhole.

2. System Penetration:

(a) End plate: No data were observed.

(b) Waterproof Casing Coating: The coating was worn away, and the end plate was heavily corroded.

(c) Drainage Opening for Conduit Interior: The drain plug could not be opened.

(d) Vent Pipe for Conduit Interior: The vent terminated in the manhole.

(e) Seal Around Conduit: The seal around the condensate line was ineffective.

Conduit.

1. Conduit Coating: The coating was less thick on the top of the conduit than on the bottom.

2. Exterior Surface of Conduit: The exterior surface of the conduit was in excellent condition.

3. Interior Surface of Conduit: There was slight corrosion of the section that had been cut out of the conduit. A corrosion pit in the invert extended about 15 percent through the shell.

4. Inside of Exposed Conduit: There were watermarks on both the insulation and the invert of the conduit.

Thermal Insulation.

1. Insulation Condition: The insulation had partially fallen off the pipe.

2. Surface Temperature of Insulation: The temperature was 114°F on the insulation and 119°F on the pipe surface. Since the line was turned off, the

high temperatures indicated that there might be a leak in a nearby closed isolation valve.

Heat-Carrying Pipes. There was minor corrosion on the top of the supply pipe and some pitting on the bottom quadrant.

Summary

Table Il summarizes the findings of the field inspection at Pensacola NAS, FL.

Table Il

Summary of Heat Distribution Systems at Pensacola Naval Air Station, FL

Site	Type of System	Site Classification (CE-301.21)	Age (Years)	Type of Line	Depth of Burial	Soil Resistivity (ohm/cm^3)	Soil pH	Condition*
1	Cl-FR	A	3	steam	7	2.5 ft-225,000 5 ft-140,000 10 ft-34,000	--	C
2	Cl-FR	A	5	steam	4	2,5 ft-225,000 5 ft-140,000 10 ft-34,000	--	C
3	Cl-FR	A	3	steam	3-4	--	--	C
4	Cl-FR	A	7	steam & condensate	4-5	--	--	C
5	Cl-FR	A	5	steam	6	--	--	D
6	S-R conduit trench	A	27	steam & condensate	--	--	--	B
7	manhole	A	not known	--	--	--	--	ID
8	Cl-FR	A	8	steam	6	5 ft-220,000 10 ft-200,000	7.05	D

*Definitions:
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace
ID = insufficient data for a rating

APPENDIX J:

ADDITIONAL SITE INSPECTION DATA AT LOCATION 7, GRAND FORKS AFB, NORTH DAKOTA

Team Members

Ellen G. Segan, CERL-EM
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Introduction

This location was inspected on August 23-26, 1983, to obtain additional soil data for use in clarifying the classifications of eight previously surveyed sites. Sites 1, 2, 3, 6, 7, 8, 9, and 10 were inspected, as well as an additional shallow trench site, number 11. Soil pH and resistivity were determined, the upper 3 ft of soil were examined, and observation wells were installed to monitor the future water table location.

Site Observation

Site #1

Location. 4 ft east of manhole 604.

Date of System Installation. 1958.

Age of System. 25 years.

Depth to Conduit Invert. 7.5 ft.

Evidence of Excess Heat Loss. Grass growth was sparse, and four vents to the conduits were steaming.

Soil Condition. The soil was a loam with a pH of 7.2. The soil resistivity was less than 2000 ohm/cm^3 at all depths measured, and the water table was 4 ft, 10 in. below the ground surface. The site classification is Class A--corrosive.

Site #2

Location. About 200 ft south of the southwest corner of Building 418.

Date of System Installation. 1956.

Age of System. 27 years.

Depth to Insulating Concrete Invert. 4 ft.

Evidence of Excess Heat Loss. No grass was growing over the line, and the steel tape was hot when it was removed from the observation well.

Soil Condition. The soil was a silt loam with a pH of 7.0, and the soil resistivity was 600 ohm/cm^3 or less at all depths measured. The water table was 6 ft, 8 in. below the ground surface. The site classification is Class A--corrosive.

Site #3

Location. About 200 ft northwest of the northwest corner of Building 410.

Date of System Installation. 1978.

Age of System. 5 years.

Depth to Bottom of Concrete Trench. 4 ft.

Evidence of Excess Heat Loss. None was observed.

Soil Condition. The soil was a silt loam with a pH of 6.5, and the soil resistivity was 1150 ohm/cm^3 or less at all measured depths. The water table was 8 ft, 7 in. below the ground surface. The site classification is Class A--corrosive.

Site #6

Location. About 30 ft east of Building 212.

Date of System Installation. 1979.

Age of System. 4 years.

Depth of Bottom of Concrete Trench. 2 ft.

Evidence of Excess Heat Loss. None was observed.

Soil Condition. The soil was a silt loam, with a pH of 6.6 and a resistivity of 2750 ohm/cm^3 or less at all depths measured. The water table was 3 ft, 8-in. below the ground surface. The site classification is Class A--corrosive.

Sites #7 and #8

Location. 200 ft north of Building 118.

Date of Installation. 1967 for site 7 and 1976 for site 8.

Age of System. 16 years at site 7, and 7 years at site 8.

Depth to Conduit Invert. 5 ft.

Evidence of Excess Heat Loss. None was observed.

Soil Condition. The soil was a loam, with a pH of 7.0 and a resistivity of 1500 ohm/cm^3 or less at all depths measured. The water table was 10 ft, 4-in. below the ground surface. The site classification is Class B--corrosive, according to FCGS 15705, and Class A--corrosive, according to CE-301.21.

Site #9

Location. 3 ft southwest of the southwest corner of manhole 101.

Date of System Installation. 1973.

Age of System. 10 years.

Depth to FRP Conduit Invert. 5 ft.

Evidence of Excess Heat Loss. Grass was sparse over the steam line.

Soil Condition. The soil was a silt loam, with a pH of 7.5 and a resistivity under 500 ohm/cm^3 at all depths measured. The water table was 11 ft, 10-in. below the ground surface. The site classification is Class B--corrosive, according to FCGS 15705, and Class A--corrosive, according to CE-301.21.

Site #10

Location. 6 ft southeast of the above-ground shallow trench intersection west of Building 229.

Date of System Installation. 1977.

Age of Trench. 6 years.

Depth to Bottom of Shallow Trench. 2 ft.

Evidence of Excess Heat Loss. None was observed.

Soil Condition. The soil was a loam, with a pH of 7 and a resistivity of under 250 ohm/cm^3 at all depths measured. The water table level was 3 ft, 8-in. below the ground surface. The site classification is Class B--corrosive, according to FCGS 15705, and Class A--corrosive, according to CE-301.21.

Site #11

Location. 4 ft northeast of manhole 103.

Date of System Installation. Unknown.

Depth to Bottom of Shallow Trench. 2 ft.

Evidence of Excess Heat Loss. None was observed.

Soil Condition. The soil was a silt loam with a pH of 7.1. The soil resistivity was 1300 ohm/cm^3 or less at all measured depths, and the water table was 6 ft, 2-in. below the ground surface. The site classification is Class A--corrosive.

Summary

Table J1 summarizes the soil data for the eight sites resurveyed at Grand Forks AFB, ND.

Table J1

Summary of Soil Condition and Site Classification at Grand Forks AFB, ND

Site No.	System Type	Depth (Bottom of System)	Age (Years in 1982)	Condition*	Site Classification CE-301.21	Site Classification FCGS 15705	Water Table Aug 83	Water Table Sep 83	Soil Resistivity (ohm/cm³) 2.5 ft	5 ft	7.5 ft	10 ft	15 ft	Soil pH
1	Conduit	7.5 ft	24	C/D	A	A	4'10"	8'0"	1950	1200	525	off-scale	--	7.2
2	Insulating Concrete	4.0	26	D	A	A	6'8"	7'3"	600	320	66	off-scale		7.0
3	Shallow Concrete Trench	4.0	4	B	A	A	8'7"	4'11"	1150	1100	--	600	125	6.5
9	FRP	5.0	9	D	A	B	11'10"	11'10"	480	280	165	18	off-scale	7.5
11	Shallow Concrete Trench	2.0	--	--	A	A	6'2"	6'2"	1300	1200	315	360	off-scale	7.1
7&8	Conduit	5.0	15 & 6	C/D	A	B	10'4"	8'8"	1500	1500	1230	720	98	7.0
6	Shallow Concrete Trench	2.0	3	C	A	A	3'8"	3'8"	2750	2200	1650	1160	1000	6.6
10	Shallow Concrete Trench	2.0	5	A	A	B	3'8"	4'5"	205	230	180	94	off-scale	7.1

*Definitions:

A = efficient
B = efficient with minor problems
C = not efficient--repair
D = not efficient--replace

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