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**GEOHERMAL DEICING OF HIGHWAYS
AND BRIDGE STRUCTURES**

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U.S. Department of Energy

Idaho Operations Office • Idaho National Engineering Laboratory

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ABSTRACT

This report presents preliminary cost estimates prepared for the Colorado Department of Highways regarding deicing of highways and bridge structures.

FOREWORD

The Geothermal Technical Assistance Program was developed under the premise that the majority of groups or individuals with available geothermal resources do not have the experience or manpower necessary to do a preliminary engineering and economic feasibility evaluation for geothermal energy projects. In order to disseminate technical information and to facilitate expanded use of geothermal energy resources, assistance was provided through FY-1981 in a consulting format on a first-come, staff-and-funds-available basis. Technical assistance can relate to conceptualization; engineering; economics; water chemistry implications for environmental, disposal, and material selection considerations; and planning and development strategies. This report is one of a series adapted from consultation provided to requesters either through in-house efforts or through limited efforts sub-contracted to local engineering firms. The Geothermal Technical Assistance (GTA) reports in this series, which are listed below, will be available early in 1982 to those with interest in specific geothermal applications.

<u>GTA Report No.</u>	<u>EG&G Report No.</u>	<u>Title</u>
1.	EGG-GTH-5512	<u>Aquaculture Facility Potential at Boulder Hot Springs, Boulder, Montana</u>
2.	EGG-GTH-5521	<u>Preliminary Geothermal Disposal Considerations, State Health Laboratory, Boise, Idaho</u>
3.	EGG-GTH-5573	<u>Geothermal Conversion at Veterans Hospital, Boise, Idaho</u>
4.	EGG-GTH-5574	<u>Geothermal Applications for Highway Rest Areas</u>
5.	EGG-GTH-5575	<u>Geothermal Applications for a Tannery</u>
6.	EGG-GTH-5599	<u>Preliminary Conceptual Design for Geothermal Space Heating Conversion of School District 50 Joint Facilities at Pagosa Springs, Colorado</u>
7.	EGG-GTH-5617	<u>Selected Geothermal Technical Assistance Efforts (comprising short descriptions of ten space heating projects, five district heating projects, and three heat exchanger projects)</u>

<u>GTA Report No.</u>	<u>EG&G Report No.</u>	<u>Title</u>
8.	EGG-2137	<u>Geothermal Source Potential and Utilization for Methane Generation and Alcohol Production (subcontractor report)</u>
9.	EGG-2138	<u>Geothermal Source Potential and Utilization for Alcohol Production (subcontractor report)</u>
10.	EGG-2139	<u>Potential Geothermal Energy Applications for Idaho Elks Rehabilitation Hospital (subcontractor report)</u>
11.	EGG-2144	<u>Technical Assistance Report on a Geothermal Heating Utility for Lemmon, South Dakota (subcontractor report)</u>
12.	EGG-2145	<u>Economic Analysis for Utilization of Geothermal Energy by North Dakota Concrete Products Company (subcontractor report)</u>
13.	EGG-2146	<u>Geothermal Feasibility Analysis II for Polo School District No. 29-2, South Dakota (subcontractor report)</u>
14.	EGG-2147	<u>Preliminary Feasibility Study of Heating and Cooling Alternatives for Nebraska Western College, Scottsbluff, Nebraska (subcontractor report)</u>
15.	EGG-2148	<u>Inventory of Thermal Springs and Wells Within a One-Mile Radius of Yucca Lodge, Truth or Consequences, New Mexico (subcontractor report)</u>
16.	EGG-2149	<u>Space Heating for Spa Facilities at Ojo Caliente, New Mexico (subcontractor report)</u>
17.	EGG-2150	<u>Geothermal Heated Office Building at Glenwood Springs, Colorado (subcontractor report)</u>
18.	EGG-2151	<u>Final Report--Dickinson Geothermal Study, Dickinson, North Dakota (subcontractor report)</u>
19.	EGG-2152	Cancelled
20.	EGG-2153	<u>Comparison of Two Options for Supplying Geothermal Energy to the Veterans Administration Medical Center, Marlin, Texas (subcontractor report)</u>

<u>GTA Report No.</u>	<u>EG&G Report No.</u>	<u>Title</u>
21.	EGG-2154	<u>Geothermal Utilization at Castle Oaks Subdivi- sion, Castle Rock, Colorado (subcontractor report)</u>
22.	EGG-2155	<u>Space Heating for Twin Lakes School Near Gallup, New Mexico (subcontractor report)</u>
23.	EGG-2156	<u>Pumping Tests of Well Campbell Et Al. No. 2, Gila Hot Springs, Grant County, New Mexico (subcontractor report)</u>
24.	EGG-GTH-5739	<u>Geothermal Deicing of Highways and Bridge Structures</u>
25.	EGG-GTH-5740	<u>Assessment of a Geothermal Application at Tucson, Arizona</u>
26.	EGG-GTH-5741	<u>Heat Pump Systems for Spring Creek, Montana</u>
27.	EGG-GTH-5779	<u>Pipe Selection Guide</u>

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GEOHERMAL DEICING OF HIGHWAYS AND BRIDGE STRUCTURES

INTRODUCTION

A review of the available literature on systems for deicing roadways indicates a lack of empirical data that can be used to confirm assumptions and computations for such projects, especially large projects such as contemplated in the Glenwood Canyon area. It is strongly recommended that the characteristics and availability of an adequate geothermal resource at a reasonable transmission distance be confirmed and that experimental programs be considered to establish or verify design criteria and objectives. In particular, it appears desirable to investigate the feasibility of using an insulating aggregate or other insulating material beneath roadway paving to reduce back losses, thereby reducing the heat load and cost of roadway heating systems. It may also be desirable to investigate the feasibility of innovative designs employing passive heat pipe grids for heating roadway and bridge structures. Designing bridge deck heating systems involves consideration of systems that will not impair the structural integrity of the bridge works, or the roadway surface, in the event of system leakage or failure. Additionally, piping grids cannot generally be placed in aggregate beneath roadway pavement on bridges. Thermal expansion-contraction effects may be greater in heating systems for bridge decks. Systems which might be considered include fluid heating grids embedded in pavement, heat pipe grids in pavement and similar grids located on the underside of bridge decks. Fluid systems embedded in pavement will require circulation of an antifreeze solution in a closed system, heat exchange equipment, and the geothermal supply and disposal systems.

DEICING OF HIGHWAYS

Based on information provided by the Colorado Department of Highways and other available data, a preliminary unit cost estimate for geothermally deicing highways in the Glenwood Canyon area was developed. The costs are based on a system for maintaining an ice-free roadway surface when air temperature is 25°F and snowfall is at a rate of 1/2 in. per hour. Based on vendor and handbook information it is estimated that a heat rate of 55 to 60 Btu per hour for each square foot of roadway surface will provide an ice-free roadway under these conditions.

Design and spacing of roadway heating grids are functions of the required heat rate, the mean fluid temperature, and the pipe diameter and material. With other conditions fixed, pipe spacing will be reduced as the mean temperature of the fluid or the pipe diameter is reduced. It appears impractical to attempt to attain a fluid exit temperature approaching 35 to 40°F due to the required pipe density and the attendant increased head loss and cost.

Available geothermal resource data indicates near-surface geothermal water may be available at temperatures approaching 125°F. Capital costs for roadway heating are based on a supply temperature of 120°F, a mean temperature of 100°F in the heating grid, and an exit temperature of 80°F. Based on available information, it is believed that the required heat rate can be supplied by a pipe grid composed of 1-1/4 in. polyethylene pipe for the spacing of 10 to 12 in., installed beneath a 4-in. concrete roadway. At a heat rate of 55 Btu/hr/sq ft, each lane-mile of 11-1/2-ft of roadway will require about 170 gpm of hot water to provide the estimated 3.34×10^6 Btu/hr, under design conditions. Similarly, heating of shoulder areas will require a flow of about 115 gpm to provide the estimated 2.3×10^6 Btu/hr for each mile of 8-ft-wide shoulder. It is suggested that a lower heat rate and less dense pipe grid be used for reasons of economy, perhaps a grid composed of 1-1/2 in. polyethylene at a spacing of 15 to 18 in.

For cost estimating, it is assumed that two to four lanes of highway are contiguous so that supply and discharge lines connected to heating grid circuits are located at approximately 280- to 140-ft intervals respectively. Supply, discharge, or return piping and headers are assumed to be of asbestos-cement fabrication. Due to the expected high mineral content of the geothermal water, heat exchanger costs are included. These costs are based on a minimum number of heat exchangers, preferably one per well. Stainless steel type-316 plate heat exchangers are specified. However, final material selection and design must be based on the temperature and quality of the geothermal supply. Inclusion of heat exchangers in the system design will likely result in a reduction of the available grid inlet-temperature by 10°F or more. It is important to obtain higher geothermal temperatures to compensate for heat exchanger losses and to minimize heat exchange costs. If direct circulation of geothermal water is acceptable, the heat exchanger costs should be neglected. In either case, surface disposal of the expended geothermal fluid is assumed.

An adequate basis for estimating production well depth is not available. A 500-ft production well and pumping from 300 ft is arbitrarily assumed to allow an estimate of pump horsepower and a preliminary cost estimate for the production system. A single well, producing 900 gpm, can supply heat for one mile of a four-lane roadway with two 8-ft shoulders under the foregoing conditions. The estimated horsepower required for pumping is: 75 hp for production, 50 hp for circulation. No credit or penalty is assumed for gravitational effects due to topographical differences between production, utilization, and discharge sites. It should be noted that year-round operation may be necessary to overcome the large thermal inertia of the roadway system and to reduce thermal cycling and attendant expansion-contraction effects, which may damage the roadway under some circumstances. System drainage must be provided to prevent freeze damage in circulating water systems. Closed-circulation systems using an antifreeze solution as a heat transfer medium should be considered for roadway and bridge-deck heating. Table 1 gives preliminary estimates of unit costs of heating systems for the roadway heating described.

TABLE 1. PRELIMINARY UNIT COST ESTIMATES FOR GEOTHERMAL ROADWAY HEATING
(\$-Per-Mile Basis)

Item	Unit Cost/Mile	Cost four-lanes, two shoulders
Well and pump	\$ 50,000	\$ 50,000
Circulation pump	5,000	5,000
Heat exchanger	50,000	50,000
Roadway grid ^(a)	120,000/lane	480,000
Shoulder grid ^(a)	85,000/8-ft shoulder	170,000
Piping, headers ^(a)	240,000	240,000
Controls, valves, etc.	20,000 (two lanes)	40,000
	SUBTOTAL	1,035,000
Design (10%)		103,500
Contingency (10%)		103,500
	TOTAL	\$1,242,000

a. Use of black steel in place of polyethelene grid pipe and asbestos cement headers and supply and return piping will tend to increase installed costs for these items by 100 to 200%.

DEICING OF BRIDGE STRUCTURES

It appears that installation of heating systems beneath bridge decks may be feasible for bridge designs, that include an enclosed air space beneath the deck, with the deck forming the upper surface of the enclosure. Accommodation for adequate drainage in the event of system failure would allow routing distribution piping through the enclosed space. The amount of heat supplied by the distribution pipe will be almost negligible as compared to the heat needed for deicing of the bridge-deck unless the pipe is very large (greater than 10-in. diameter) and the water temperature is quite high (greater than 200°F). Bridge decks will require approximately 100 Btu per hour/per square foot of surface for deicing under the conditions previously specified for roadway deicing. A two-lane, 23-ft-wide bridge deck would require about 2300 Btu/hr per running foot. At a pipe temperature of 200°F, a 10-in. pipe could provide only about 800 Btu/ft to the enclosed air space, assuming the air space is at a temperature of 70°F.

For a more probable temperature of 120°F, only about 240 Btu/hr per foot of 10-in. pipe is available to the air space, or about 10% of the required heat. If the bottom surface of the air space is well insulated, the heating required will be significantly reduced. The unit cost for bridge deck heating systems seem likely to be two to three times the unit cost for roadway heating, based on the increased unit heat load, the design constraints, and insulation costs which may be near \$0.75 per square foot of deck for 2 in. of sprayed polyurethane insulation on the lower inside surface of the air space enclosure.

Based on information from the Colorado Department of Highways and other available data, a preliminary unit cost estimate for geothermally deicing highway bridge structures also was developed. The estimates are based on systems for maintaining an ice-free roadway surface when air temperature is 25°F and snowfall is at a rate of 1/2 in. per hour. A heat rate of 80 Btu per sq ft is believed to satisfy this heating requirement. Cost estimates are on a per-mile basis for four-lane bridge decks. A supply temperature of 100°F, an exit temperature of 55°F and a flowrate of 860 gpm are used to develop preliminary capital cost estimates for two bridge deck deicing

system designs. Systems considered are: 1) a closed circulation grid with an antifreeze solution as the heat transfer medium, 2) a heat pipe system. System costs are based on the use of black steel pipe at a spacing of 12 in. for each system. Rationale for costing of the geothermal supply system and the closed circulation pipe system is similar to that for costing of roadway deicing systems. Major differences are the pipe material selected and the operating temperatures used in developing the estimates. Estimated costs for the heat pipe system include only one supply header, whereas two may be required, depending on the design of the system. Use of a single header will require placement beneath the centerline of the bridge deck.

Operating and maintenance cost for heat pipe systems can be expected to approach 25% less than comparable circulation systems due to reduced power costs for pumping and reduced maintenance costs for heat pipes as compared with pipe systems for circulation of thermal fluids.

Table 2 shows estimated capital costs for the above systems together with estimated costs for an optional heat pipe system as of October 30, 1979.

Due to the significant difference between estimated costs for the two heat pipe systems and the significant design differences, it seems advisable to experimentally determine performance of the two systems before making a final selection. It should be noted that the optional heat pipe system will require approximately twice the geothermal flowrate required by the competing heat pipe design, because the exit temperature of the geothermal fluid is assumed to be about 80°F. This will result in higher power costs for the optional heat pipe system, along with an increase in required pump horsepower. The lower-cost heat pipe system does not appear to include adequate costs for installation of the heat pipes; this cost may approach several hundred thousand dollars for each mile of four-lane bridge deck. An additional cost of about \$35/ft should be assessed for transmission-supply pipe in all cases.

TABLE 2. PRELIMINARY UNIT COST ESTIMATES FOR GEOTHERMAL BRIDGE DECK HEATING
(four lanes, \$ per mile basis)

<u>Item</u>	<u>Pipe Grid</u>	<u>Heat Grid</u>	<u>Optional Heat Pipe</u>
Well pump	\$ 50,000	\$ 50,000	\$ 50,000
Circ pump	5,000	--	--
Heat exchangers	50,000	--	--
Supply pipe, headers	240,000	160,000	--
Pipe grid, heat pipes	1,000,000	500,000	1,800,000 ^(a)
Controls, valves, fittings	40,000	30,000	30,000
Disposal piping	<u>145,000</u>	<u>145,000</u>	<u>145,000</u>
Subtotal	1,530,000	885,000	2,025,000
Design (10%)	153,000	88,500	202,500
Contingency (10%)	<u>153,000</u>	<u>88,500</u>	<u>202,500</u>
	\$1,836,000	\$1,061,000	\$2,430,000
Total	\$7.60/ft ²	\$4.40/ft ²	\$10.00/ft ² ^(b)

a. Heat pipes, headers \$1,200,000; installation \$600,000.

b. \$8.13/sq ft for heat pipes, headers and disposal (installed cost).