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CULVERT THAWING SYSTEMS

by

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June 1994

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Disclaimer

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Abstract

An extensive review of culvert thawing practices throughout Alaska and northwest Canada has been summarized. Particular attention has been given to electrical thawing methods. This review was conducted through telephone discussions with Alaska Department of Transportation and Public Facilities (AKDOT&PF) and Canadian transportation personnel, as well as through a complete literature search.

Based on the review, conclusions are drawn and ideas for a safe and economical portable electrical thawing design are proposed.
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1. Introduction

Roadway culverts in the North are subject to seasonal freezing during winter and spring. Culverts blocked with ice restrict the flow of winter ground water and spring runoff. During winter, ground water can continuously feed streams which either flow through culverts or over roadways causing icing. During spring breakup, daytime melting must be carried through culverts. Frozen culverts thaw slowly compared to surface snow and ice. This delay can create an ice dam, which allows water onto the roadway and causes refreezing problems at night.

Various methods have been used to keep culverts open. Passive methods such as large culverts, bridges, dikes, and runoff channels have been tried but are not always economically feasible. Where passive methods cannot be used, active methods for culvert thawing are required. Active icing control and prevention methods include the following:

- thaw pipes installed inside culverts to carry steam, hot water, or warm antifreeze as supplied by an external heat source (portable boiler, solar panels, etc.);
- portable boilers to provide steam or hot water to probes which are forced through blocked culverts;
- oil barrel stoves ("moose warmers") to heat upstream flows; and
- electrical thaw cable (also known as thaw wire or heat tape) installed inside culverts. [1,2]

This report first discusses existing culvert thawing methods. Second, a portable electrical thawing method is proposed. Electrical methods are attractive because they are simpler and less expensive than steam boiler methods. Careful consideration must be made of safety issues associated with both steam and electrical methods of culvert thawing.

A former AKDOT&PF manager indicated that there were more positive attributes of this project and its anticipated next phase than just saving Alaska road system maintenance money. He said that the idea behind looking again at electrical thawing of culverts came from AKDOT&PF workers in the field. He wanted to have this project succeed so that field workers would get the message that their ideas count and that they are listened to when they communicate up the chain of command.
Section 2 of this report summarizes our discussions with AKDOT&PF personnel and Canadian transportation personnel concerning present methods and equipment used to thaw culverts. Section 3 summarizes the published literature on roadway icing and culvert thawing methods. Section 4 describes a portable electrical alternative to culvert thawing. Section 5 summarizes our conclusions and recommendations.

2. Existing Methods for Culvert Thawing

Extensive telephone interviews were conducted with Alaskan and Canadian transportation personnel experienced in culvert thawing practices. Appendix 1 contains a listing of telephone contacts pursued during this investigation. This listing includes some contacts who were not reached in person. However, these contacts led to other personnel in the same office who were helpful. Below is a summary of the major points and general themes distilled from these conversations.

2.1 Steam Boilers

After numerous telephone conversations, we concluded that steam boilers have definite applications, such as ditch thawing, that would be difficult to accomplish by other means. Even if alternative thawing techniques such as electric thaw cables were shown to be useful in many situations, it would be impractical to totally replace steam boilers for culvert and ditch thawing.

Steam boilers are expensive to purchase, operate, and repeatedly certify. Steam boilers also have safety problems. Deaths of AKDOT&PF workers were reported due to carbon monoxide poisoning from boiler heater exhaust displacing oxygen in ditches. Another incident occurred when the end of a boiler ruptured during a thawing operation at Turnagain Arm in south central Alaska. Traffic snagging steam hoses is considered an additional operational hazard. Boilers have a 6 to 10 year life span, cost approximately $90,000 including the flatbed truck for transport, and generally require a two-man crew.

Hot water heaters also exist for providing hot fluid to previously installed pipes. No specifics were mentioned about hot water heaters during our conversations with AKDOT&PF personnel, but we assume that they are safer than higher pressure steam boilers. In evaluating the cost of such systems, one must consider installation costs to put pipe into the culverts, and connect time when actually using the system. Northwest
Territories transportation personnel no longer use steam but instead have switched to 1500 psi hot water.

2.2 Thaw Cables

Thaw cables were used fairly extensively in Alaska prior to an unfortunate electrocution case in Eagle River approximately five years ago. We understand that, since that time, no electric thawing devices have been used in Alaska. AKDOT&PF has approved standards for thaw cable installations which are permanently installed and utilize 60 Hz 120/240 V AC power from the local utility. We are not aware of standards for electric thawing devices powered by portable electric generators or welders.

Several proponents of electric thaw cables indicated they thought such devices had appropriate uses, were cost effective, and worked well in the past. The opinion was expressed that safety considerations could be satisfactorily addressed through installation and inspection of electric thawing systems by qualified individuals, and that regular inspection was important, particularly prior to start-up at the beginning of the winter season. Use of thermostats was suggested to turn systems off when not needed. Systems should also be manually turned off during the summer season. These considerations are not applicable to thawing devices powered by portable electrical generators.

The original thaw cables used by AKDOT&PF were brightly colored and attracted the unwelcome attention of children, who would disturb the installation and remove cables from ditches. Later cables were specified to be a brown color which was reported to be less attractive to children.

During travel by one of the authors through the Yukon Territory on the Alaska Highway in early May 1994, thaw cable installations were examined. At one site, identification found on the thaw cables specified voltage ratings of 120/208/240 V, power ratings of 2300/6800/9000 W, and 550 ft. lengths. Thaw cable was strung through a road culvert and up a stream bed for several hundred feet. The outer rubber coating had melted off the cable in many places. The cable termination was a three conductor female connector that was about 3 inches in diameter. There was no effort made to protect the thaw cable with rigid conduit. There was no power source connected to the cable, but it was evidently used that season since thaw channels through the stream bed ice followed the cables.
2.3 Welders

Welders have been used in the past to provide electric current to conductors placed in culverts for the purpose of thawing ice. Several welders have apparently been destroyed by this practice. Although we have not obtained any written documentation about these welder failures, we are led to believe that such units were operated outside their approved range. For example, most welders have a specified duty cycle of between 30% and 50%. If this duty cycle rating is exceeded, overheating of the welder will occur, consequently reducing service life. In addition, a welder is designed to operate as a constant current source under normal conditions, which means sustaining a welding arc. This arc, a conducting path of hot gas, has more resistance than a typical pipe or rod that may be used to thaw a culvert. Thus, if a welder is used to thaw a pipe or to heat a pipe or rod placed in a culvert, it will supply more current at a given setting than if it were used as a welder. It is, therefore, very easy for an uninformed operator to unknowingly abuse the welder while thinking that the current setting is within a safe operating range.

Lincoln Electric Co. bulletin E695.1, entitled "Thawing Frozen Water Pipes" is included in Appendix 2. This bulletin notes that DC arc welders are often used to thaw frozen water pipes. The company does not recommend this practice, and notes that this method of pipe thawing is not a recommended procedure by the Canadian Standards Association (CSA). Hazards from using welders for thawing pipes as listed in bulletin E695.1 include fire; explosion; damage to wiring, which may cause an unsafe condition; damage to pipes; and "burning up" the welder. However, the bulletin does include some suggestions for safe thawing procedures. Lincoln Electric markets a product called "Linc-Thaw" that protects DC welders by limiting current from the welder with fuses. It also includes a DC ammeter that measures the actual current delivered to the pipe being thawed.

3. Literature Review

A computerized literature search was performed to identify all pertinent publications on culvert thawing systems. Few published papers or reports appear to exist.

One definitive report on prevention and control of culvert icing is a Cold Regions Research and Engineering Laboratory (CRREL) report of studies from 1966 to 1970 [1]. The CRREL report contains both American and Russian experience in icing control. Field testing results from 1966 to 1970 are included, based on test sites throughout Alaska.
Electrical heating cables and drainage channel improvements proved to be the "most promising."

Empirical relationships for determining steady state heating cable thermal requirements were developed from field tests and theoretical models in the CRREL report [1]. The results indicate that the thawed tunnel radius \( R \) is related to the heating cable output \( H \) by

\[
R = 0.401H
\]

where \( R \) is in inches and \( H \) is in watts per linear foot (W/ft) of cable. Assuming an overall cable efficiency which approaches 40% (actual heat used to melt the thaw tunnel), the time \( T \) needed to reach the final tunnel radius \( R \) for a heat cable output of \( H \) is given by

\[
T = 20.63H
\]

where \( T \) is in hours and \( H \) is again in W/ft. Heating requirements near the ends of culverts are greater because of increased heat loss to the air. Doubling or tripling the heat output near the culvert ends is suggested to mitigate refreezing problems at the ends. The CRREL report suggests values ranging from 15 to 35 W/ft near the openings [1].

The equations above apply to steady state conditions. During the transient period when the thaw tunnel radius is expanding, the thermal characteristics can be quite different. The tunnel radius as a function of time approaches its final value roughly logarithmically, with both the initial steepness of the curve and the final radius a function of the heating cable output. Therefore, doubling of the heating cable output will yield a given tunnel radius in much less time, as expected. Figure 1 shows the expected thaw tunnel radius versus time for four different heating cable ratings from 10 W/ft to 40 W/ft. This figure was created from equations for transient thaw behavior given in the CRREL report [1].

Given a desired tunnel radius, the most energy and time efficient manner to thaw the culvert is to use as large a heating cable output as possible to reach the desired radius and then reduce the output to maintain the thaw tunnel. During spring breakup, melt waters may be warm enough to maintain the tunnel without additional heating.

Heat tape installations also need to account for the random behavior of ice formation around culvert openings. To ensure that a path is created from the water source to the culvert opening, a wide area near the culvert opening (upstream end) may need to be
heated. Each culvert site has unique heating requirements, mainly on the upstream side, based on ground topology.

![Thaw Tunnel Radius versus Time for Different Heat Tape Ratings](image)

**Figure 1.** Thaw Tunnel Radius versus Time for Different Heat Tape Ratings

Solar assisted culvert thawing projects are reported in several sources [2,6]. Zarling reports on an Alaskan project [2] and Alberta Transportation Research and Development reports on a project in Alberta, Canada [6]. Both references report primarily on the solar hardware and installation without much discussion of the thermal requirements for culvert thawing. One noteworthy conclusion from both studies is that security was a major problem. Solar panels in both locations were likely targets of vandalism.

An improved culvert design which expedites the natural thawing mechanisms inside the culvert during spring breakup is proposed by Johansen and Lozana [3a and 3b]. This design does not use any active heat source to thaw the culvert but, rather, uses a coarse gravel fill around the culvert to permit early natural thawing.
A comprehensive description of the mechanisms which cause icings is given by Carey [4]. This report also includes a discussion of both passive and active icing prevention methods. Passive methods discussed include road grade changes, large drainage structures, increasing pond storage, dams, staggered culverts, and filtration dikes. Active methods include steaming, fuel oil heaters ("moose warmers"), electrical heating cable, blasting, and chemicals. The discussion of electrical heating cables is a subset of that which appears in the CRREL report [1].

An annotated bibliography covering American and Russian experiences through the late 1960's is available [5].

O'Brien describes the Alberta Transportation Research and Development Branch experience with generator powered thaw cable and thaw cable powered by a local utility connection [7, 8].

In the first case [7], a 6 kW generator was connected to 130 feet of Pyrotenax electric heat cable which operated at 40.9 Watts/foot with 220 V applied. The current requirement was approximately 24 A. A span of two to three hours was reportedly enough operating time per application. The heating cable cost approximately seven years ago was $580 (Canadian). The 6 kW generator was leased for $350/month. The report noted that several sites could be served by the same generator, resulting in virtually no incremental cost. Previous costs using "heavy equipment with a steaming apparatus" were estimated to be $1,000 per visit. Several visits were required in a typical year.

In the second case [8], a 220 V power line supplied a 100 ft Pyrotenax stainless steel electric heat cable designed for operation at 48.4 Watts/foot. A 24 hour timer relay and a variable thermostat were recommended for installations not checked daily. The installed cost of the heat cable was approximately $1,700 (Canadian) in 1984. With maximum power cost estimated at $300/year and annual savings of $1,000 from not using a front end loader and a 2 person steaming system, the electric culvert thawing device was expected to pay for itself in two to three years and save approximately $700/year thereafter.

4. Alternative Electrical Thawing Design

Based on safety concerns, economics, and thaw wire recommendations from numerous transportation personnel, we believe that a low voltage, high current culvert thawing
system may be a promising alternative. Electrical equipment is less expensive than steam boiler equipment and low voltage electrical systems enhance safety.

A low voltage constant-current transformer built for pipe thawing was kept in stock at the Fairbanks Lincoln Electric Co. dealership for several years. It did not sell and the unit was returned to the Anchorage supplier. This transformer was manufactured by C. K. Systematics and carried the model number IB 300, "Pipe-N-Hot". It was designed to operate at a 60 Hz primary voltage of 120 V or 230 V.

We have been told that the province of Alberta, Canada highway department uses or has used low voltage electric thawing devices for culverts. However, these rumors have not been substantiated even after numerous telephone calls to individuals referred to us that are alleged to be knowledgeable about the subject.

Prior to hearing the rumor described in the preceding paragraph, we had decided that a safe, efficient culvert thawing system could be built using steel rod or pipe connected to a low voltage step-down transformer (60 V or less secondary voltage). The rod or pipe would be electrically insulated from the culvert by brackets rugged enough to withstand mechanical forces expected during periods of high water volume or if the pipe was surrounded by ice. For portable applications, a truck-mounted 15 to 20 kW, 240 V AC generator powered by a gasoline or diesel engine could be used to provide the energy source. With the heating rod or pipe previously installed in the culvert, the step-down transformer could be skidded to the electrical connection point. A three-conductor #8 wire flexible cable with Arctic insulation could connect the 240 V primary winding of the step-down transformer to the truck-mounted generator. Heavy electrical conductors such as #2 copper are required to connect the low voltage side of the transformer to the heating element (a steel rod or pipe) in the culvert. If the transformer must be located a long distance from the heating element, conductors larger than #2 copper would be required, as can be determined through use of the table on the top of page 3 in Appendix 2.

High current, low voltage heating conductors may be constructed of steel rod or pipe. For example, one-half inch diameter steel rod has a resistance of approximately 0.29 milliohm/ft. To obtain a heating value of 20 W/ft would require a current of about 260 A. A heating value of 20 W/ft is considered appropriate for several culvert thawing applications [1]. One inch galvanized water pipe has a resistance of 1.26 milliohms/ft and would require a current of 126 A to dissipate 20 Watts/ft. For a total heating conductor length of up to 400 ft, a 4:1 transformer turns ratio would step down a 240 V primary
winding voltage to a 60 V secondary voltage at 125 A. A 10 kW to 12 kW transformer would be adequate for this purpose. A non-ventilating design may be desirable to eliminate snow, dirt, and gravel from getting into the unit. By using an ammeter and a 60 A adjustable autotransformer ("Variac") in the 240 V primary circuit, the current in the heating conductor may be adjusted to the desired value for the length of conductor used and the rate of heating desired.

It appears that a low voltage, high current electric culvert thawing system may provide a significant cost advantage over steam thawing devices. Considering initial cost, a steam generator is estimated by AKDOT&PF to cost between $45,000 and $50,000, including an insulated enclosure. The steam generator and enclosure are typically mounted on a 24,000 lb GVW flat-bed truck with a purchase cost of approximately $45,000. A 15 kW, 240 V, 60 Hz diesel engine driven electric generator costs about $15,000. A 12 kW step down transformer costs approximately $1,200. Electric cables required to connect the generator, transformer, and heating conductors are estimated to cost $1,000. The generator and transformer would easily be transported with a 1/2 ton pickup truck with a purchase price of about $25,000.

A gasoline engine driven generator costs about one-third as much as a diesel driven unit, but we are told that a diesel engine has a five to eight times greater service life than a gasoline engine.

AKDOT&PF assumes a seven year steam boiler lifetime, a boiler replacement cost of $480/month (1995 rate), and a fuel and maintenance cost of $200/month for the central region and $440/month for the northern interior region. A 24,000 lb GVW flat-bed truck has, according to AKDOT&PF, a $205/month replacement cost and $415/month (1995 rate) fuel and maintenance cost. A steam generator often uses a crew of two persons at an estimated cost of $72/hour.

Assuming a fifteen year diesel engine, generator, and transformer lifetime, we roughly estimate a diesel electric generator set and transformer replacement cost to be \((7/15)(17,200/50,000)(\$480/\text{month}) = \$77/\text{month}\). It is difficult to estimate the monthly fuel and maintenance cost of an engine-driven generator without knowing the average number of hours it will be in service. However, assuming 8 kWh/gallon of diesel fuel, the cost per hour for supplying a 10 kW load is approximately $1.20. It seems intuitively reasonable that maintenance of a diesel-electric generator set will be, at worst case, no more costly than the maintenance of a steam boiler system. The replacement cost of a 4
wheel drive (4WD) one-half ton pickup truck is estimated to be \( (25,000/45,000)(205) = \$114/\text{month} \), and the assumed fuel and maintenance cost is 75\% that of the flat-bed truck or \$311/\text{month} \). Assuming that a one-person crew can operate the low-voltage, high current electric culvert thawing system, that person would cost an estimated \$36/\text{hour} \).

To summarize, using the above approximate assumptions, the initial cost of a steam generator and flat-bed truck is about \$95,000 \), while the initial cost of a 15 kW diesel electric generator set with step down transformer, cables, and 4WD pickup truck is approximately \$42,200 \). This is a \$52,800 \) difference. Considering replacement costs and fuel and maintenance costs of only the trucks of the steam and electric thawing systems, since fuel and maintenance costs of the electric system are difficult to quantify without knowing the average rate of use per month, the steam system costs approximately \$1,100/\text{month} \) while the electric system costs an estimated \$500/\text{month} \). Since a one-person crew should be sufficient for the electrical thawing system, there should be a savings of up to \$36/\text{hour} \) in labor costs compared with the steam thawing system.

We have not considered the cost of permanently installing the heating conductor in a culvert. It would probably be similar to that of a permanently installed thawing pipe for hot glycol or steam.

A major advantage of a low voltage system is a large increase in human safety relative to 120 V or 240 V heat cables. A 60 V secondary voltage could be arranged to be only 30 V with respect to electrical ground (and Earth ground) through use of a center-tapped secondary winding. Electrocution at 30 V is nearly impossible. In addition to this, safety of a portable system is enhanced because AKDOT\&PF personnel would always be attending an installation if a generator were present and connected. This is a notable difference between a permanent installation connected to a utility power system and the portable type of system we are envisioning.

5. Recommendations

We recommend that a portable, low-voltage electric culvert thawing system as described in Section 4 be designed and field tested. This system would utilize a step-down transformer and a suitably sized, truck mounted 240 V AC generator driven by a gasoline or diesel engine. Heating conductors may be permanently mounted on insulating supports attached to culvert walls so that all a maintenance person would have to do is connect the
transformer secondary winding terminals to the heating conductor, start the generator, and adjust the heating conductor current for the desired heat rate.

We believe that a low-voltage system is inherently safer than conventional 120/240 V heat tape installations. Also enhancing the safety of a portable system is the presence of AKDOT&PF maintenance personnel while the unit is in operation.

It appears that substantial cost savings may be realized through use of portable, low-voltage electric culvert thawing systems instead of steam systems. While it is recognized that steam systems may not be universally replaced, there may be a sufficient number of sites suitable for portable electric thawing to make this approach attractive to AKDOT&PF.

We intend to follow-up this report with a proposal to AKDOT&PF for the design of a portable low-voltage culvert thawing system, including prototype construction, instrumentation, and field testing through a winter season.
6. References


[6c] E. Hildebrand, "Two O'Clock Creek Culvert Thawing Device 1986/87 Winter Operation", Report No. ABTR/RD/RR-87/01, April 1987, Alberta Transportation Research and Development

### Appendix 1

**List of Telephone Contacts, Alaska:**

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<tr>
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<tr>
<td>Blanning, Mike</td>
<td>Asphalt Foreman, Maintenance and Operations (M&amp;O), Fairbanks</td>
<td>907-451-5282</td>
</tr>
<tr>
<td>Braley, Alan</td>
<td>Airport Engineer, Fairbanks International Airport</td>
<td>907-474-2530</td>
</tr>
<tr>
<td>Brownfield, Boyd</td>
<td>Director of M&amp;O</td>
<td>907-266-1500</td>
</tr>
<tr>
<td>Bunch, William</td>
<td>Equipment Operator III</td>
<td>907-678-5205</td>
</tr>
<tr>
<td>Connor, Billy</td>
<td>Construction Engineer, Design and Construction (D&amp;C)</td>
<td>907-474-2479</td>
</tr>
<tr>
<td>Dahle, Clyde</td>
<td>Project Manager, Aviation Design, D&amp;C</td>
<td>907-266-1694</td>
</tr>
<tr>
<td>Eagle, Wayne</td>
<td>Manager, M&amp;O, Tok</td>
<td>907-883-5128</td>
</tr>
<tr>
<td>Esch, David</td>
<td>Research Engineer, Engineering and Operations Standards</td>
<td>907-465-6956</td>
</tr>
<tr>
<td>Hahn, Earl</td>
<td>Equipment Operator III</td>
<td>907-678-5205</td>
</tr>
<tr>
<td>Herrman, George</td>
<td>Tazlina Area Manager, M&amp;O, Southcentral District</td>
<td>907-822-3222</td>
</tr>
<tr>
<td>Langel, Ken</td>
<td>Formerly with AKDOT&amp;PF, now with H.C. Price Co.</td>
<td>907-278-4400</td>
</tr>
<tr>
<td>Levasseur, George</td>
<td>District Manager, M&amp;O, Southcentral District</td>
<td>907-451-5148</td>
</tr>
<tr>
<td>McHattie, Robert</td>
<td>Geotechnical Engineer, Technical Services, D&amp;C</td>
<td>907-451-2236</td>
</tr>
<tr>
<td>Milne, Clark</td>
<td>Director, M&amp;O, Northern Region</td>
<td>907-451-2295</td>
</tr>
<tr>
<td>Morberg, Keith</td>
<td>Chief, Design, D&amp;C</td>
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</tr>
<tr>
<td>Nelson, Keith</td>
<td>Fleet Manager, Statewide Equipment Fleet</td>
<td>907-243-7671</td>
</tr>
<tr>
<td>Phipps, Jack</td>
<td>Denali Area Manager, M&amp;O</td>
<td>907-451-5283</td>
</tr>
<tr>
<td>Rasmussen, Loren</td>
<td>Chief, Design and Construction Standards</td>
<td>907-465-2960</td>
</tr>
<tr>
<td>Regar, Jason</td>
<td>Fairbanks Station Foreman, M&amp;O</td>
<td>907-451-2205</td>
</tr>
<tr>
<td>Stuller, Dwight</td>
<td>Dalton Area Manager, M&amp;O</td>
<td>907-451-5282</td>
</tr>
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Appendix 1 (cont.)

List of Telephone Contacts, Canada:

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<thead>
<tr>
<th>Name</th>
<th>Organization and Details</th>
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<tbody>
<tr>
<td>Abt, Mark</td>
<td>Alberta Transportation and Utilities, Research and Development</td>
<td>403-422-2750</td>
</tr>
<tr>
<td>Clark, Clyde</td>
<td>Alberta Transportation and Utilities, Bridge Engineering Branch</td>
<td>403-427-6913</td>
</tr>
<tr>
<td>Close, Al</td>
<td>Manager at Whitehorse</td>
<td>403-667-3710</td>
</tr>
<tr>
<td>Frazier, Rob</td>
<td>Acting Manager, Whitehorse</td>
<td>403-667-3710</td>
</tr>
<tr>
<td>Hagan, Stu</td>
<td>Regional Bridge Engineer, Alberta Transportation and Utilities, Peace River District</td>
<td>403-624-6280</td>
</tr>
<tr>
<td>Kollias, Tas</td>
<td>District Engineer, Calgary, Alberta</td>
<td>403-297-6311</td>
</tr>
<tr>
<td>Lamb, Fred</td>
<td>Project Manager, M&amp;O, Yellowknife, NWT</td>
<td>403-874-6972</td>
</tr>
<tr>
<td>Lund, Mr.</td>
<td>Chief Road Engineer, Vancouver, B.C.</td>
<td>604-387-6772</td>
</tr>
<tr>
<td>McGowen, Cindy</td>
<td>Assistant District Engineer, Alberta Transportation and Utilities, Calgery</td>
<td>403-297-6311</td>
</tr>
<tr>
<td>Nagano, George</td>
<td>Dawson City, Yukon</td>
<td>403-993-5344</td>
</tr>
<tr>
<td>Pienpsch, Brian</td>
<td>Alberta Transportation and Utilities, Peace River District</td>
<td>403-624-6280</td>
</tr>
<tr>
<td>Poach, Ron</td>
<td>Alberta Transportation and Utilities, Carstairs Office</td>
<td>403-337-3577</td>
</tr>
<tr>
<td>Ramatar, Jay</td>
<td>Executive Director, Bridge Engineering Branch, Alberta Transportation and Utilities</td>
<td>403-427-6912</td>
</tr>
<tr>
<td>Sembsmoen, Victor</td>
<td>Acting Foreman, Beaver Creek, Yukon</td>
<td>403-862-7227</td>
</tr>
<tr>
<td>Wehers, Rick</td>
<td>Beaver Creek, Yukon</td>
<td>403-862-7227</td>
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<td>Zacharia, Zach</td>
<td>Alberta Transportation and Utilities, Research and Development</td>
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</tbody>
</table>
Appendix 2

Lincoln Electric Bulletin E695.1
THAWING FROZEN WATER PIPES

While arc welders are not specifically designed for thawing frozen water pipes, they have been used for this purpose. The reason for this is that arc welders are a good source of low voltage, high current electric power which, when flowing through the pipe, causes it to heat and melt the frozen water. Properly used, welders are a fast low cost method of thawing pipes without digging or the need of an open flame. When pipes are accessible, however, they can be thawed more safely, easily and quickly by careful use of a small electric heater or heat lamp. Because of the potential dangers in thawing pipes with high electric current, it is of the utmost importance that it be done only by qualified people after carefully reviewing the information in this bulletin.

WARNING: The use of electric current to thaw frozen pipes if not done properly can result in fire, explosion, damage to wiring which may make it unsafe, damage to pipes, burning up the welder, or other hazards. This Bulletin will give you some appropriate methods and safeguards. However, responsibility for the application of this information and using good judgment in the use of a welder to thaw pipes is yours.

NOTE: Pipe thawing is NOT a recommended procedure by the Canadian Standards Association (CSA).

HERE'S HOW IT WORKS

When electric current passes through a metal pipe, the pipe's electrical resistance causes heat to be generated which thaw the frozen water. Here are the factors which affect the time and amperage required for thawing.

PIPE MATERIAL

WARNING: Thawing cannot be accomplished on non-conductive pipe, such as plastic, or on metallic pipe with non-conducting joints in the section to be thawed.

Copper and steel are typically used for most water pipe. Steel pipe has a higher electrical resistance and heats more rapidly than copper when a given amount of electric current passes through it. (Read item 3 under “Pipe Thawing Do's and Don'ts” on page 2.)

SIZE OF PIPE

A small diameter pipe has a higher resistance because of its smaller cross sectional area and will therefore heat more rapidly than a large diameter pipe when a given amount of current is passed through it. Thus, it takes higher current and longer times to thaw large diameter pipes. The time and current required for thawing are about the same for any length of pipe, except that as the length increases, the voltage drop increases, which in turn causes a reduction in current. It is best to apply the current across the shortest area of pipe in which the freezing has occurred.

CURRENT (amperage)

The amount of heat in the pipe is most dependent upon the amount of electric current available. The greater the current passed through a pipe, the greater the heat generated. With twice as many amperes, the heating rate is four times as fast. If the number of amperes is increased three times, the heating rate is nine times as fast.

TIME REQUIRED

The time required for thawing different sizes of steel pipe using different currents is given in the following table. Copper pipe requires more current than steel pipe for the same thawing time. To thaw 1/2-inch copper pipe, increase the figures for steel pipe by 10%. Increase the current for steel pipe by 25% to thaw 3/4-inch copper pipe. Larger copper pipes require an even larger percentage increase of current. Of course the lower the temperature the longer it will take to thaw the pipe.

<table>
<thead>
<tr>
<th>Amperage (a) and Time for Thawing Steel Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Size (in.)</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>150</td>
</tr>
<tr>
<td>125</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>75</td>
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<td>50</td>
</tr>
</tbody>
</table>

(a) Actual amperage as read on a meter. Actual amperage is higher than welder control setting when thawing pipe.

EQUIPMENT REQUIRED

Because they have high current capabilities and can be used where there is no source of electricity, the larger gasoline or diesel engine driven DC welders are commonly used for thawing. To prevent damage to the DC welder, use of a Lin-C-Thaw is recommended. The Lin-C-Thaw is not applicable to AC welders; it only works on DC. Its advantages and uses are described on pages 3 and 4.
Most constant current, industrial AC and DC welders and most air cooled engine driven welders can be used for thawing. Smaller capacity welders, if suitable for pipe thawing, sometimes have a specific selector switch setting for thawing. If in doubt, check the specifications or instruction manual for your machine or write to the manufacturer.

**PIPE THAWING DO'S AND DON'TS**

**WARNING:** Under no circumstances should any pipe thawing activity take place without a knowledgeable person in attendance during the entire time. Pay special attention to Item 3 below. Failure to follow proper procedures and to use good judgement can result in fire, explosion, damage to wiring which may make it unsafe, damage to pipes, burning up the welder or other hazards.

1. Isolate the frozen section of pipe. This can be done by turning various faucets on until the specific frozen areas are determined.

2. Confine all pipe thawing activity within your property boundaries and to fire hydrants or water mains in the immediate vicinity of your property. DO NOT attempt to thaw pipes by making connections to neighboring houses.

3. The frozen section of pipe must complete the electrical circuit from the welder. Always be certain that there are no insulated joints or plastic pipe sections that could prevent the electric current from passing through the frozen section of pipe. Such interruptions will cause the current to flow through alternate paths if they complete the circuit. These alternate paths could take the form of gas pipes, neutral conductors or grounding wires of the electrical system which may not have sufficient electrical capacity, causing them to burn open (and therefore not be able to perform their intended function in the future) or become so hot as to cause a fire hazard or explosion. Further, even if the frozen section does complete the electrical circuit these same types of alternate paths may still be in electrical parallel and draw current from the welder. Under these conditions they will need to be temporarily disconnected during the pipe thawing operation.

For example, the sketches below show various connections. In a situation shown in Fig. 2, if the barn has electric power a check must be made that a parallel path is not formed by the neutral conductor or the grounding wire of the electrical system. In Fig. 3, a check must be made that a parallel path is not formed by the grounding wire to a disposal or built-in dishwasher.

4. Both cable connections should be as close to the frozen area as possible. A small empty pipe in the circuit could get hot before a larger frozen pipe thaws. This could melt solder in copper pipes, causing water damage, or the empty pipe may become so hot as to become a fire hazard.

5. The cables to be used must be large enough to handle the current and should be kept as short as possible. Recommended cable sizes are shown on page 3.

6. Except when actually thawing, turn the welder off. Follow all instructions and safety precautions for the welder including those relating to the hazard of electric shock. Also, failure to do this may cause arcing when the cables are connected and result in a hole in the pipe.

7. Connect a cable on one side of the frozen section. Connect the other cable on the other side. If using a Lin-Thaw (see page 3) to protect your DC welder, follow the installation instructions in the Lin-Thaw sections.

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**Figure 1**

- FIRE PLUG
- LINC-THAW
- DC WELDER
- WATER MAIN
- FROZEN SERVICE PIPE

**Figure 2**

- AC WELDER
- FROZEN PIPE TO BARN

**Figure 3**

- KITCHEN
- FROZEN PIPE IN WALLS
- AC WELDER
MINIMUM RECOMMENDED COPPER CABLE SIZES

<table>
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<th>Amps</th>
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<th>175</th>
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</tr>
</tbody>
</table>

except that you are not to turn the welder on at this time.

The connection to the pipe must be good. Clean the pipe, preferably by sanding with coarse emery paper, before connecting. Bad connections may cause arcing and result in a hole in the pipe. Poor connections will overhear, resulting in loss of thawing current.

8. Be sure the supply valve is open so there is water pressure on the frozen section. Open a faucet on the other side of the frozen section so that when the heat melts a thin layer of ice next to the pipe, water can flow. The continued flow of water will melt the remaining ice.

9. Before turning the power source on, be certain to properly adjust its output so it will not be overloaded. Pipe thawing involves heavier sustained loads than welding. Because pipe thawing establishes close to a short across the welder terminals, actual amperes drawn are always greater than indicated by the current control dial. Therefore, specific pipe thawing instructions for each type machine must be followed.

Also, since the welder may overheat if it is overloaded, leaving the machine in a cold place or outside will help to keep it cool.

a. Follow the ‘Procedures’ on page 4 for some Lincoln welders.

b. For welders not listed on page 4, check the machine instruction manual for specific pipe thawing current settings and then turn the power source on.

c. CAUTION: DO NOT use constant voltage power sources for pipe thawing because they have no control for limiting amperage.

10. As soon as water starts to flow, turn the welder off and allow the continued flow of water to melt the remaining ice.

11. Be sure the welder is off before removing leads. After the welder leads are removed from the pipe, be sure to reconnect any wires of the electrical system which were disconnected in step 3, and recheck the grounding system to make certain it will perform its intended function.

LINC-THAW™

Protects Your DC Welder (The Linc-Thaw cannot be used with AC welders. Also, it cannot be used on the DC output of the Weldanpower AC/DC — see page 4.)

<table>
<thead>
<tr>
<th>Type Welder</th>
<th>Maximum Actual Amperage (Not Dial Setting)</th>
<th>Fuse Size Lag Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-225/3-AS</td>
<td>160</td>
<td>110</td>
</tr>
<tr>
<td>SA-200</td>
<td>200</td>
<td>150</td>
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<tr>
<td>SA-250</td>
<td>250</td>
<td>200</td>
</tr>
<tr>
<td>SAE-300 and SAM 300</td>
<td>300</td>
<td>250</td>
</tr>
<tr>
<td>SAE-350 and 400/</td>
<td>400</td>
<td>350</td>
</tr>
<tr>
<td>SAM-400n</td>
<td>400</td>
<td>450</td>
</tr>
<tr>
<td>SAF-650 or SAM-650n</td>
<td>600</td>
<td>450</td>
</tr>
</tbody>
</table>

On SAM welders, use the Stick Electrode stud and set controls for variable voltage. Never use constant voltage settings to thaw pipe.

INSTALLATION

Connect the electrode and work cables from the welder to one side of the Linc-Thaw. The cables to be connected to the pipe are connected to the other side.

The Linc-Thaw operates in any position. You can mount it on the welder frame or in any convenient location.
The DC meter indicates the actual thawing current. This lets you adjust the welder to the values listed on page 1 or to the maximum suitable amperage.

The fuse in the Linc-Thaw limits the actual amperage draw to the maximum safe limit of the welder.

WHEN ORDERING

Although the Linc-Thaw is designed for use with Lincoln engine driven DC welders, it can also be used with Lincoln motor-generator and belt welders and other makes and models of DC welders. Always specify the generator capacity and the model number when ordering so you get proper fuse.

Use only the lag fuses listed in the table above. Fuses in the Linc-Thaw carry more than rated current because they are not in cartridges.

PROCEDURES (DC MACHINES USING LINC-THAW)

1. Connect the cables to the pipe per the instructions on page 2.

2. Set the current control.
   
   DC-225/3-AS — Set the 'Current Range' control on 100.
   SAE Welders — Set the 'Current Control' using the 'Large Electrode' dial or arrow for the amperage required.
   SA-200 Welder — Set the 'Current Range Selector' to 200 amperes.
   SA-250 Welder — Set the 'Current Range Selector' to 200 amperes.
   SAF-650, SAM-400 or SAM-650 Engine Driven — Use '300-575' stud or lower.

3. Set the fine adjustment control to minimum. These are identified as follows:
   
   DC-225/3-AS — 'Fine Adjustment'
   SAE — 'Job Selector'
   SA-200 — 'Fine Current Adjustment'
   SA-250 — 'Fine Current Adjustment'
   SAF-650 Engine Driven — 'Open Circuit Voltage'
   SAM-300, 400 & 650 Engine Driven — 'Variable Voltage Control'

4. If the electrode cable is connected to the 'Positive' stud of the Linc-Thaw, the polarity switch should be in the 'Electrode Positive' position. The meters will then read up scale.

CAUTION: Do not move the polarity switch on SAM welders while the machine is running. This will cause arcing and the eventual failure of the switch. Start the welder only after making these connections.

5. Increase the control identified in step 3 until the Linc-Thaw meter indicates the required current. If a Linc-Thaw is not available, leave the control at minimum.

6. If step 5 does not provide the proper current, stop the welder. Increase the current control setting. Start the welder and make the final adjustments as in step 5.

7. CAUTION: NEVER change the current control under load. This will cause arcing and eventual failure of the control.

PROCEDURES (AC MACHINES)

Linc-Thaw Not Used. Make sure you have read this bulletin completely before proceeding.

1. Weldanpower 225G7 and Weldanpower 250 (G9 Pro; D10 and D10 Pro) — Set the 'Electrode Polarity' switch on 'AC' (do not pipe thaw on 'DC' settings with this particular machine — the higher short circuit current obtained can overload the machine). DO NOT use the maximum tap or the CV tap. The 'Output Selector' switch and the 'Output Control' can be set to suit the pipe thawing requirements, as long as "AC" is used. CAUTION: Do not rotate the 'Electrode Polarity' or the 'Output Selector' switches while the machine is under load. This will cause arcing and eventual failure of the switches.

2. Weldanpower 150 and Weldanpower 150 AC/DC — Set the 'Current Selector Switch' to suit the pipe thawing requirements. Use AC only! CAUTION: DO NOT rotate or move these switches if the machine is under load. This will cause arcing and eventual failure of the switches.

3. AC-225-S, AC/DC-225/125 or AC-275 Arc Welder (60 HZ only) — Machines must be set for 75 amps AC only! This is the only tap rated for pipe thawing. CAUTION: Using other taps or changing the controls under load will cause rapid failure of the control and/or the welder.