Cape Dorset Water Supply Main
Rehabilitation Review

Trow Associates Inc.

Summary Report
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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Introduction

In August 2004, the Government of Nunavut retained Trow Associate Inc. (Trow) for the rehabilitation of the Cape Dorset Water Supply Main. An initial field visit was completed prior to conducting the peer review of the existing water main design. Temporary remedial measures for 2004 as well as a more permanent design for 2005 were then submitted.

The following provides a summary of the findings and remedial measures as previously submitted and included within this report.

Peer Review

Introduction

A review has been conducted of the Concept Brief and construction documents prepared by Dillon Consulting (Dillon) for the improvements to the Cape Dorset water system. The Planning Study for this project as prepared by Reid Crowther and Partners Limited (RCPL) was also reviewed to provide background and perspective for the review of the Dillon documents. Reports detailing these reviews have been prepared and are summarized as follows.

Reid Crowther and Partners Limited Planning Study (Refer to Tab 2)

Trow is in general agreement with the recommendations of this study. This includes agreement with various features of the proposed system including the use of stainless steel piping and internal heat tracing. There is agreement with the principle findings of the heat loss computations including the estimated temperature depression. The RCPL study does not address the issue of thermal expansion of the pipeline.

Dillon Consulting Concept Brief (Refer to Tab 3)

Trow agrees, generally, with the system proposed in the Concept Brief. This includes the following features of this system:

- The selection of 75 millimetre diameter piping,
- The selection of 50 millimetre as the insulation thickness,
- The use of stainless steel piping, and
- Internal heat tracing of the pipeline.

The heat loss computations assume a higher value for the insulation conductivity than is typical for polyurethane foam. This assumption does not cause a substantial difference between the estimates of temperature depression presented in the Concept Brief and independently calculated during the course of this review. The assumption of a lower insulation conductivity might have resulted in the selection of a lower rating for the internal heat tracing cable.

The recommendation that use of the immersion heaters was not required for ambient conditions warmer that -30°C is not supported by computations within the report.

The Concept Brief does not consider the issue of thermal movement of the piping or the need to accommodate this thermal movement.

Various dates within the Concept Brief suggest the preparation of this report within a very compressed time frame. Completion of the draft of this document permitted the acquisition and shipping of the piping within the 2000 shipping season.

Construction Documents (Refer to Tab 4)

The drawings provided for review are annotated as "Record" drawings. In general the drawing and contract documents convey the scope of work within this project. There are several variations between these drawings and the system constructed in the field including:

- The location of the expansion loop, and
- The location of the roadway crossing.

The attached memorandum provides detailed comments upon the drawings. These comments include the following observations:

- No width dimension is provided for the junction boxes. The constructed boxes are narrow and the electrical junction boxes have been installed on the outside.
- There is potential for confusion regarding the spacing for the junction boxes. It is clear that the intended length of the heat trace cables was 70 metres. It appears this has been misinterpreted as the spacing between the junction boxes leading to a question regarding freeze protection at the un-powered junction boxes.
- The drawings and constructed works contain an expansion loop between the Heater House and the Truck Fill Station. No documents have been provided describing the reasons for the provision of this expansion loop.
- Details are not provided regarding pipe restraint as part of the provisions to accommodate thermally induced pipe movement.

Observations

The expansion loop is a structure with very low stiffness, resulting in significant movement of the piping as a result of small loads. Much of the displacement of the piping down slope, below the expansion loop, is the result of gravity loads upon the expansion loop.

Provision for expansion requires measures to fix the piping at points susceptible to damage from movement and measures to accommodate thermal expansion. Piping restraint was not incorporated into the Cape Dorset Water Supply Main.

Change Orders to the contract lead to the conclusion that the contractor was instructed to adjust the control system to provide for continuous operation of the heat trace system during winter. No documents detailing the reason for this modification have been provided for review.

Independent Heat Loss Calculations (Refer to Tab 6)

Heat trace calculations for the water supply pipeline have been prepared and are attached. The following are the principle findings of these calculations:

- During winter conditions (-30°C ambient) water should arrive at the Truck Fill Station at approximately 3°C if the immersion heaters are in operation. The arriving temperature is close to the freezing point if the heaters are not in operation.
- For a temperature difference across the insulation system of 50°C, heat loss is less that 10 W/m. The installed heat trace capacity is 22 W/m.
- Continuous operation of the present heat trace cable could raise the temperature 116°C above ambient if sufficient time past to establish steady state conditions.

Thermal expansion along the 1,100 metre stainless steel pipeline is between 140 centimetre and 210 centimetre due to seasonal and operating variations in temperature.

Heat Trace Related Issues (Refer to Tab 7)

Comment has been sought for various issues related to the heat tracing system for the water supply pipeline. These have included the electrical metering of the heat trace system and the current operating mode of this system.

Electrical Metering

Currently there is an analogue ammeter in the Truck Fill Station indicating total current drawn by the heat trace system. This meter indicates, in a general sense, that the heat trace system is in operation.

Prior to the most recent modifications, failure of the heating cable would lead to a large and observable change in the indicated current. The current system does not have the necessary resolution to detect the failure of a single heat trace cable.

A digital ammeter would provide sufficient resolution to detect the failure of a single cable but would not provide the location of the heat trace fault. The digital ammeter represents a lower cost but incomplete solution.

An alternative scheme is based upon current detection for each heat trace cable or each powered junction box, and a central status indicator in the Truck Fill Station. This more costly solution clearly locates the faulted cables. This system would be substantially more convenient from an operational point of view, especially in determining the location of faults during winter.

Additional information can be developed for the heat trace monitoring system following the selection of a preferred system.

Heat Trace Operating Mode

Direction to alter the heat trace control to provide continuous operation during winter was included in Changer Order No. 3, approved by the Department in September 2002. Documentation in support of this change has not been provided for review. It is presumed that this modification was carried out for sound reasons. High energy costs in Cape Dorset together with the previous successful history with heat trace forming part of the tank refill cycle suggests that further review is in order. Background data, including the following measurements, is necessary for this review.

- Data to determine the thermal balance of the system and the rates of heat loss including water temperatures at the lake, at the input and discharge sides of the Heater House and at the input to the Truck Fill Station.
- Confirmation of the electrical consumption of the immersion heaters.
- Confirmation of the flow rate through measurement of tank refill rate.

Summary of 2004 Stabilization Program (Refer to Tab 8)

The proposed remediation program for 2004 was based on a clamp-on sleeve system secured to the exterior of the insulated pipe and attached by cable to the existing pipe support system as per Dillon's previous recommendation. The sleeves were to be installed in two locations, specifically at the Heater House and below the expansion loop.

The procedure and sketches for the 2004 remedial program are included in the Tab 8. A summary of the actual works done is also provided. The actual works are not consistent with the procedures as outlined, and have raised some concerns. There is insufficient restraint of the pipeline below the Heater House. The fixity at the road crossing also raises concerns with respect to possible inappropriate movement of the 11-1/2 degree bend. The concerns arising from the 2004 remedial measures are addressed within the 2005 Pipe Stabilization Program.

Summary of 2005 Stabilization Program (Refer to Tab 9)

The 2005 Stabilization Program outlines the procedure for the 2005 program and is detailed in Tab 9. It addresses the issues raised from the 2004 program. Sketches of the welded stainless steel assemblies and installation are included. Further manufacturer technical information relating to the rock anchor installation is also provided.

Peer Review Water Supply Pipeline
Planning Study
Cape Dorset, NWT
January 1997
Reid Crowther Partner Limited

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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Introduction

The following review is based upon a copy of the Water Supply Pipeline Planning Study, prepared by Reid Crowther Partner Limited (RCPL) dated January 1997, as provided by the Government of Nunavut. This review has been conducted in the absence of the Terms of Reference for this report, as these have not been provided.

Existing System Background

1. This section is generally consistent with Trow Associates Inc.'s (Trow) understanding of the water system in Cape Dorset.

2. Section 2.1 , page 3, paragraph 2 – It is Trow's understanding that chlorine is currently added prior to loading in trucks.

3. Section 2.3.2 – Phone service has been subsequently reinstated to Heater House.

Analysis of Existing System

1. Section 3.1 – Explanation of System Methodology is consistent with Trow's understanding of this system.

2. Section 3.2.1 – This section provides comments regarding the performance of the existing immersion heaters and theoretical temperature rise. Trow is in agreement with the reported rise of 3.1°C if the pumping rate is in imperials gallons per minute. The temperature rise increases modestly to 4°C if the quoted pump rate is in USGPM. This temperature change should have been observable with the gauges. Thus, we support the conclusion suggesting further investigation of the gauges and immersion heaters.

3. Section 3.2.2 – The first paragraph might be better included as the final paragraph of section 3.2.1. The computations support the view that the pipeline is not flowing full but this observation is not directly stated. Trow accept the opinion that velocities are high enough to scour debris and deposit this material in the storage tank.

4. In general Trow agrees with the various heat loss calculations provided. The following comments are provided regarding the heat loss computations:

    a. The heat loss computations do not present the units of calculation.

    b. Sketch SK1 referred to in the text has not been provided as part of the report reviewed.

    c. Computations are based on the nominal size of the piping (3″) and a soft conversion of an insulation thickness of 1 ½″.

    d. Assumed insulation thermal conductivities are typical of the values for fibreglass and polyurethane.

e. The assumption that the more poorly insulated portions of piping (at the couplings) is the initial section of piping is a reasonable assumption that provides a conservative estimate of temperature depression.

f. Trow agrees with the calculated temperature depression.

g. No computations are provided for the temperature rise due to the heat trace cable. Trow has confirmed, through independent computation, the estimated temperature rise of 0.5°C (Refer to Tab 6 – Thermal Computations).

Water Demands and Capacity

1. The water demand computations are based upon a population estimate and the Municipal and Community Affairs (MACA) water consumption, which is typical of how such estimates are prepared.

2. The text does not clearly set out a recommended consumption and thus a recommended storage size. A design flow rate for the pipeline has not been clearly set.

Operation and Maintenance Costs

1. The observation of high operating costs for the Heater House due to electrical consumption is reasonable independent of the data due to the size of the heaters and the method of operation.

2. The tables clearly summarize the data as provided by the various sources.

Formulation of Alternatives

1. RCPL agree with the earlier opinion of Wardrop for a pipeline based system in lieu of a haul road. Trow agrees that this is the only viable alternative.

2. Based on the reported condition of the piping the opinion that replacement was required seems appropriate.

3. Rearrangement of the material of the chapter to first set the service conditions might clarify the process followed to reach the conclusions.

4. Trow agrees with the opinion that stainless steel is an appropriate material.

5. Trow agrees with the recommendation for internal heat tracing.

6. Trow agrees with the reluctance to recommend HDPE piping in this application.

7. The substantiation for the three preceding recommendations is not clearly presented.

Recommendations

1. Trow generally agree with the recommendations.

2. A design flow rate has not been recommended for the pipeline.

3. The recommendation of phased replacement may carry some logistical challenges arising from the need for specialized equipment. Phasing would require any specialized equipment to remain in the community for more than one construction season.

4. A definitive selection of pipeline material has not been made

Other Issues

1. The issue of thermal expansion of the pipeline has not been addressed in the RCPL report.

2. A clear summary of the service conditions this pipeline must meet has not been set out. These service conditions include flow rate operating temperatures and frequency of operation.

Peer Review of the Water Supply
Design Concept Brief
Cape Dorset, Nunavut
Draft Report, July 17, 2000
Dillon Consulting Limited

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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Introduction

The following review is based upon a copy of the draft report, Water Supply Design Concept Brief dated July 17, 2000, prepared by Dillon Consulting Limited (Dillon), as provided by the Government of Nunavut as part of the Operations and Maintenance manual for the Cape Dorset water pipeline. This review has been conducted in the absence of the Terms of Reference for this report.

Existing System Description

1. This section is generally consistent with Trow's understanding of the Cape Dorset water system.

Site Inspection

1. Little comment can be provided regarding this section as this is a reporting of observations during a site visit.

2. It is noted that the field visit was conducted 12 days before the report was issued. This suggests a compressed time frame for the project.

3. Page 3. Several comments and suggestions from the Hamlet are reported, and it appears that many of these questions were addressed in the final works. Several of these suggestions could not be incorporated such as removable insulation, plastic piping and flanged joints. In most instances these matters are addressed in later sections of the report.

4. The Hamlet expressed the suggestion that the pipeline be anchored to the hill, which does not appear to be incorporated into the constructed works.

Population and Consumption Projections

1. The population projection has been extended to the year 2022, from the earlier date of 2016 used in the Reid Crowther Partner Limited (RCPL) report. There is a slight variation in the population from the earlier RCPL work but this variation is only 2 percent for the year 2015.

2. The following table summarizes some of the water consumption rates as presented in this report and as presented by RCPL in 1997. None of these variations in consumption rates significantly alter the selected design.

Table 1: Water Consumption Rates

Year	Water Consumption (L/c/d)	
	RCPL 1997	Dillon 2000
2000	141.0	140
2005	161.6	160
2010	185.3	182
2015	212.7	207
2020		234
2022		246

Pipeline Hydraulic Requirements

1. The value of Manning's "n" of 0.020 used in the computations is slightly higher than that typically assumed, but the resulting computations provide a conservative estimate of the pipe capacity.

2. Trow is in agreement with the recommended selection of pipe size of 75 millimetre diameter.

Heat Loss Calculations

1. The following general comments are provided:

   a. Details of the computations are provided in an appendix to the reviewed report.

   b. These computations follow methods provided in the "Cold Climate Delivery Manual."

   c. The assumed value for insulation conductivity leads to a higher estimate of heat loss.

   d. Despite various questions regarding assumptions, the reported temperature depression does not vary greatly from those values independently computed.

2. A value of 0.052 has been assumed for the insulation conductivity. No units for this parameter are provided. This value is more typical of that for fibreglass, and is the value assumed by RCPL for fibreglass in their earlier report. A manufacturer of the insulated piping system (Urecon) reports an insulation conductivity of 0.020 to 0.026 W/m°C. It has also been assumed that these are the applicable units.

3. The assumed water flow rate for the purposes of the heat loss computations is 6 litres per second. The pump capacity is reported on page 7 as 80 gpm (probably usgpm) or 5 litres per

second. RCPL reported the pump capacity as "approximately 60 gpm = 4.6 L/s = 4.6 kg/s." The higher flow rate assumed in the calculations leads to a higher estimate of heat input into the pipeline.

4. Calculations of heat loss and temperature depression were provided in the appendix to the report. Independent calculation of the temperature depression has been performed. The following observations are provided.

   a. An initial confirmation of thermal behaviour was conducted assuming a thermal conductivity of 0.052 W/m°C and a flow rate of 6 litres per second consistent with the assumptions of the Dillon report.

   b. The actual outside diameter of the installed piping is 88.9 millimetre as opposed to 77.93 millimetre as assumed in the computations. This leads to slightly higher heat loss, but the difference in computed temperature depression is inconsequential.

   c. Calculations are not provided for the lowest permissible temperature for the water leaving the Heater Building. We calculate that a leaving temperature at the Heater House of 1°C results in water arriving at the Truck Fill Station at the freezing point.

   d. Further independent computations have been performed assuming a thermal conductivity of 0.023 W/m°C, which is consistent with polyurethane foam, and a flow rate of 5 litre per second. These adjustments to the assumptions vary the estimated temperature depression by less than 1°C.

   e. Heat loss estimates have been independently calculated by Trow both for a thermal conductivity of 0.052 W/m°C and 0.023 W/m°C (Refer to Tab 6 – Thermal Computations). For conditions of an internal temperature of 4°C and an external temperature of – 50°C, the higher conductivity leads to heat loss of 22 W/m and the lower value provides an estimate of 9 W/m.

5. The recommendation for a 50 millimetre insulation thickness is supported by the heat loss estimates and is consistent with practice in the region.

6. The advice regarding non-operation of the immersion heaters reads, "… unless the temperature of the outside ambient air is below 30°C." This is likely a typographic error, and should probably read, "… **-30°C**."

7. There are no computations provided in support of the recommendation regarding the appropriate ambient temperature for operation of the immersion heaters, as is described in point 6 above. Our initial calculations indicate that the combination of an ambient temperature of -30°C and a water temperature of 0.5°C will result in water arriving at the Truck Fill Station slightly above the freezing point.

Upgrading Requirements

1. The upgrading requirements from Tee Lake to the Heater House are clearly set out with the exception that a clear recommendation regarding the provision of a new intake and pump is not provided.

2. Regarding the pipeline from the Heater House to the Truck Fill Station the following comments on the report are provided:

    a. It is reported that heat tracing with a capacity of 11.8 W/m would be suitable. (Reference is made to Section 5.0. Section 6.0 deals with the question of heat loss.) The discussions of heat loss calculations do not summarize the anticipated heat loss, but are limited to estimates of arriving temperature at the Heater House and Truck Fill Station. Section 6.0 reports that a heat trace with a capacity of 3.6 W/m would increase water temperature by 0.5 °C. There is an apparent typographic error regarding units as 3.6 W/ft is 11.8 W/m. No computations in support of this estimate are provided.

    b. Trow is in agreement with the opinion that an internal heat trace is most appropriate, but note there is no substantiation for the estimate that 20 W/m would be required for external heat tracing.

    c. Trow is in agreement with the opinion that a low technology approach is appropriate.

    d. The report indicates that a heat tracing system with a capacity of 11.8 W/m would be suitable. An independent estimate of heat loss leads to a similar requirement of 9 W/m. The installed system has a capacity of 22 W/m.

    e. The apparent intent is that the heat trace operates on a timed basis as part of the tank refill cycle.

    f. The discussion of pipeline materials addresses the most suitable materials for consideration. Cautions regarding the corrosion of copper piping due to nature of the water in Cape Dorset are appropriate. Concerns expressed regarding the challenges of heat tracing HDPE piping are well founded. The recommended alternative of stainless piping is appropriate.

3. Upgrading requirements for the Heater House are discussed.

    a. Retention of the existing building is an appropriate recommendation.

    b. It is Trow's understanding that the advice to maintain the immersion heaters as standby equipment was not incorporated into the final works.

    c. Replacement of the controls power panels and upgrading to current code requirements is appropriate.

4. Upgrading requirements for the Truck Fill Station are discussed.

a. The recommendation regarding control modifications to reduce the risk of pipeline freeze following power failure is appropriate.

b. Relocation of the fill piping to the top of the tank is discussed and an estimate is provided. No advice regarding the appropriateness of this work is provided. The pipeline has not been relocated to the top of the tank. This work does not appear to be included in the summary table.

Implementation

1. The first paragraph of this report section contains blanks for the project budget and the suggested dates for the tender of materials.

2. The suggested dates provide in this section of the report indicate a very compressed time frame for the project.

3. Acquisition of materials in 2000 with construction in 2001 was an appropriate strategy in view of seasonal and logistical issues.

Other Issues

1. Based on the date of the site visit (July 4 and 5), the date of the report (July 17, 2000) and the reported last date for Sea Lift (August 16, 2000) it appears that this project advanced within a very limited time frame.

2. The Concept Brief does not examine the issue of thermal expansion of the piping. The Brief does not address the provision of an expansion loop into the piping.

Review of the Record Drawings
December 2002
Cape Dorset Water Supply Main

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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Introduction

The following review is based on the review of "Record Drawings" dated December 2002 and Contract Documents for the Cape Dorset Water Supply Main replacement as provided by the Government of Nunavut.

General Comments

This section of the review summarizes our understanding of the compliance of the drawings and contract documents with the scope of work presented in the design brief. Items that were not included within the concept brief or record documents, including change orders, are also summarized below.

1. The drawings and specifications follow the intent of design as outlined in the Design Brief.

2. The documents are consistent with the outlined scope of work in Section 01500 of the specifications.

3. The drawing notes that topography and location of the structures in the drawing are based on information provided by others and the accuracy of information cannot be assured.

4. The main pipeline length is indicated as approximately 1,220 to 1,240 metres in the contract documents. Based on our field estimates the length of the pipeline is closer to 1,175 metres.

5. The drawings and documents address most of the issues from the "Concept Brief" with the following exception:

   a. The option to fill the Truck Fill Storage Tank from the top by realigning the pipeline to the top of an adjacent hill was not incorporated into the design. A definitive stance on this matter is not presented in the Concept Brief.

6. The drawings and contract documents reflect decisions subsequent to the Concept Brief that are not documented in the various materials we have reviewed. These include

   a. Retention of the existing piping between Tee Lake and the Heater House, together with provision of an additional pump.

   b. Provision of an expansion loop, which is referred to as an "Expansion joint".

7. The drawings are labelled as "Record Drawings" but certain changes to the design are not depicted and no documentation is provided as to these modifications. These include:

   a. The relocation of the road crossing 430 metre closer to the Truck Fill Station.

   b. The relocation of the expansion loop approximately 100 metre uphill from the mid-point of the pipeline.

   c. The number of as-built junction boxes is not indicated or revised on the drawings.

8. Further modifications by change orders include:

    a. Removal and disposal of the wood supports and the existing steel pipeline.

    b. Further modifications to the Truck Fill Station:

        - Minor Electrical modifications

        - Modifications for a new manual drain line and minor maintenance issues

    c. Change to the heat trace system to continuous operation during the winter periods of operation. No documentation was provided to explain this revision to the design brief.

    d. Supply and installation of marker posts for the junction boxes.

    e. Replacement of failed heat trace cables and re-calibration of heat trace system thermostats.

9. It is unclear where thermal movements are to be accommodated and where restraints against such movement are to be provided.

10. The installation of an emergency back-up HDPE pipeline is subsequent to the preparation of the contract documents.

Review of Scope of Work

The following summarizes Trow's understanding of the scope of work in Section 01005 of the contract document based on information provided in the drawings and contract documents. Each item outlined in the description of work is further detailed from information on the drawings. Minor changes or differences between the documents are listed.

1. Pipeline replacement work included:

    - The placement of approximately 140 metres of 63.5 millimetre stainless steel insulated pipe from the Intake Junction Box to the Heater House.

    - The placement of approximately 1200 metres of 75 millimetre stainless steel insulated pipe from the Heater house to Truck Fill Station with the existing pipeline remaining in place.

    - Change Order 5 subsequently addressed the removal and disposal of the existing pipeline. The existing pipeline was removed with the exception of the section between the Intake Junction Box and the Heater House.

2. The supply and installation of the heat trace system for the pipeline is divided as follows:

    Between the Intake Junction Box and the Heater House:
    Heater Zone 4. Load data 22 W/m at 120 volts as per specification section 15705. Drawing 107 specifies 208 volts. One junction box installed at mid-point of the pipeline.

Between the Heater House and the Truck Fill Station:
The heat trace is divided into Heating Zones 2 and 3. The termination junction box between the two zones is indicated at the expansion loop. Load data 22 W/m at 600 volts, 3.0 amps as per specification section 15705.

3. The supply and installation of pipe supports, and modification of selected pipe supports:

   Between the Junction Box and the Heater House:
   Existing supports were to be reused. Six of these were to be reset and braced. During our site visit in August of 2004 we noticed one frost jacked pipe support in this section of pipe.

   Between the Heater House and the Truck Fill Station:
   From the Truck Fill Station to station 0+680 new supports at 2.5 metre intervals were proposed and installed. The support detail on drawing 102 specifies a depth of 2 metre in overburden soil, which is likely in active layer leading to the risk of frost jacking.

   From Station 0+680 to Station 0+830 (approximately) the steel supports were reused with four (4) supports requiring to be reset.

   From Station 0+830 to Heating House the supports were reused. Drawing 101 specifies that pipe supports should be modified as per specifications. No reference to modifications of supports was found in the specifications. The support detail on Drawing 102 includes the following:

   a. Reflective warning tape; and

   b. Pipe straps at every 50 metres. The field spacing of these straps for this section of pipe is greater than 50 metres.

4. The supply and installation of the new intake line included the following:

   a. The existing intake casing, pipe, submersible pump, heat trace and screen were to remain. The pipe fittings were connected to a new 3-way valve inside the new junction box.

   b. The new intake system consists of:

      - A screen 600 millimetre x 1850 millimetre with flanged riser as by Screen Service Ltd. During our site visit in August 2004 the Hamlet staff expressed the opinion that it was never installed.

      - Submersible pump with check valve removed from outlet to permit back flow back to Tee Lake

      - Heating cable specified for the intake line is a self-regulating nickel-plated cable. Load data 10 W/m at 120 volts as per specification section 15705.

      - Anchored using concrete blocks – the distance between blocks was not specified.

   c. The New Junction Intake Box

5. The construction of vehicle crossings over pipeline

   a. One road way crossing was specified on the drawings with a culvert protection for the pipeline. The design location of the crossing is shown above the expansion loop. It was installed approximately 440 metre closer to the Truck Fill Station. The pipeline and expansion loop are on the opposite side of the road. This alignment is currently adjacent to a washed out section of terrain. There is no documentation of the Engineer approving this change.

6. Reconstruction of access road sections to work site including culvert supply and installation:

   a. No reference can be found within the contract documents indicating the location of access roadwork or culvert installation beyond what is defined as work for the above vehicle crossing.

7. Upgrades to Heater House including new door and hardware, and mechanical and electrical changes for installation of new intake.

   a. The mechanical and electrical upgrades were well documented on the drawings.

   b. The door replacement was not indicated on the drawings but is listed within the specifications.

8. Upgrades to the Truck Fill Station electrical and controls systems for the new heat trace system are shown on the electrical drawings.

Review of Drawings

The drawings are consistent with the overall intent of the design.

The following revision of the record drawings details variations, from the constructed work

Drawing 101 Pipeline replacement plan and profile

1. Drawing 101 is the first instance of expansion accommodation measure, namely the addition of an expansion loop.

2. Drawing is indicated as a "Record Drawing" – there are variations between the drawing and as-built conditions such as the location of the expansion loop and road crossing which are not shown on the drawing.

3. Topography is based on aerial map – no survey was conducted. In view of limited time frame to produce drawings this would be a reasonable option. Elevations on the contours are indicated in feet while the profile is in meters, which makes cross-referencing awkward.

4. Alignment for profile and pipeline are different for the first two hundred meters of pipeline. This however is relatively minor and would not affect the project.

5. There is no indication on the profile as to the location of the junction boxes, road crossing and expansion loop.

6. The location of expansion loop from our field is not at the mid-point of the pipeline but rather at approximately 700 metres from the Truck Fill Station and approximately 500 metres from the Heater House. No further details of the expansion loop are provided. It is unclear whether this expansion loop is intended to accommodate expansion of part or of the whole pipeline.

7. Drawing annotated with direction to retain existing pipeline. This pipeline is not currently in place, but a back HDPE pipeline has been installed. The installation of the backup pipeline is probably subsequent to the preparation of these drawings.

8. The existing wood supports are not indicated on the drawing.

9. The existing road is not indicated on the drawing.

10. For graphical clarity it would have been preferable to have different linetypes for the existing pipeline alignment and the proposed pipeline.

Drawing 102 Flow diagram and intake system

1. Existing intake: The existing intake is to remain. The only modification indicated is to move the junction boxes and control into the new junction box at the intake.

2. New intake: The spacing of concrete anchor indicated to suit profile. The intake screen is at 3.5 metres below water surface.

3. The pipe supports in overburden soil are specified as 2 metres long. This may not be sufficient to extend through the active layer leading to a risk of frost jacking.

4. The interval of the pipe straps is specified at 50 metre intervals. The field spacing for these straps is greater than 50 metres.

Drawing 103 Intake and junction box details

1. No specific comments to this drawing

Drawing 104 Electrical and miscellaneous details

1. The heat trace junction box detail does not stipulate a width for these boxes. Subsequently the constructed boxes have proven to be narrow and the electrical junction boxes were installed on the exterior.

2. The penetration detail at the wall of the Heater House does not indicate anchorage for the piping.

3. The pipeline heat trace layout drawing indicates nine (9) junction boxes on heater zone 2. The termination junction box between zones 2 and 3 is installed at the expansion loop. Heater zone 3 has nine (9) junction boxes from the expansion loop to the Heater House. Therefore this indicates a total of nineteen (19) junction boxes. This information conflicts with Drawing 107, which shows a total of sixteen (16) junction boxes.

4. The pipeline heat trace layout does not provide the distance between the junction boxes.

Drawing 105 Intake and junction box details

1. This drawing seems to have been updated to include as-built information.

Drawing 106 Electrical panel and control schematics

1. This drawing seems to have been updated to include as-built information.

Drawing 107 Electrical controls

1. This drawing seems to have been updated to include as-built information.

2. The heat trace on the new water pipeline indicates sixteen (16) junction boxes between the Truck Fill Station and the Heater House on two different heating zones. This is inconsistent with Drawing 104, which shows nineteen (19) boxes.

3. The voltage indicated between the Intake Junction Box and the Heater House is indicated as 240 volts on the drawing. The Load data from the specifications called for 120 volts.

4. The heat trace schematic seems to reflect as-built modifications. This detail represents an electrical schematic and as such, should not have been used as a layout drawing. The 70 metre/600 volt note on the drawing indicates the type of heat trace cable rather than the distance between junction boxes.

Additional Comments regarding Heat Tracing System

There is significant variation between the record drawing 101 and the constructed works. It appears that the drawing was not updated to reflect as-built conditions.

The design intent was as follows:

1. 1,220 metre of pipeline with an expansion loop at the midpoint.

2. A total of nine (9) junction boxes from the Truckfill station to the expansion loop, one termination junction box at the midpoint of the loop and another nine (9) junction boxes from

the expansion loop to the heater house; for a total of 20 – 61 metre long segments between the junction boxes for each 70 metre length of heat trace cable.

The electrical drawing shows the 70 metre heat trace cable length. We do not interpret this drawing as a layout direction. Greater clarity regarding spacing would have avoided this issue of short unheated sections of pipeline.

The constructed works were as follows:

1. The actual length of the constructed pipeline is approximately 1,175 metre

2. The expansion loop was built approximately 100 metre closer to the Heater House.

3. Nine (9) junction boxes from the Truck Fill Station to the loop for an approximate spacing of 69 metre.

4. Six (6) junction boxes from the expansion loop to the Heater House for an approximate spacing of 68.5 metre.

5. Given a certain allowance in length for curving the cable into the Y at the junction boxes there were likely unheated sections in vicinity of non-powered boxes.

Photograph No. 1: Inside Heater House

Photograph No. 2: View of pipeline from Tee Lake towards Heater House

Photograph 3: Immediately below the junction box, between the Heater House and Tee Lake. Photograph illustrates a displacement of approximately 1.5 inches.

Photograph 4: Downhill of the Heater House towards Tee Lake. The photograph illustrates a displacement of 1.25 inches.

Photograph 5: Pipe penetration through the wall of the Heater House, the condition of the caulking demonstrates piping movement.

Photograph 6: Below the Heater House. The photograph illustrates a displacement of one inch. .

Photograph 7: Section of pipeline which is elevated above the ground and the pipe profile is steeper. The displacement in the photograph is approximately one inch.

Photograph 8: Elevated section of pipeline immediately above where the road crosses underneath the pipeline. The photograph illustrates a displacement of approximately one inch.

Photograph 9: At the road crossing looking towards Heater House. Photograph shows the pipe profile.

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Photograph 11: One of the modified pipe supports.

Photograph 12: Photograph of one of the straps over the pipe. The strap is larger in diameter than the outside diameter of the pipe jacket.

Photograph 13: Approximately 35 metres uphill from the expansion loop. Paint marks illustrate almost no movement of the pipeline at this location.

Photograph 14: The pipeline is displaced off centre on the pipe support. Paint marks indicate little movement.

Photograph 15: The uphill leg of the expansion loop illustrates a lateral displacement of approximately two inches at the two pipe supports. (See photograph 16)

Photograph 16: Lateral displacement of pipeline on uphill leg of expansion loop.

Photograph 17: Lateral displacement of pipeline on downhill leg of expansion loop.

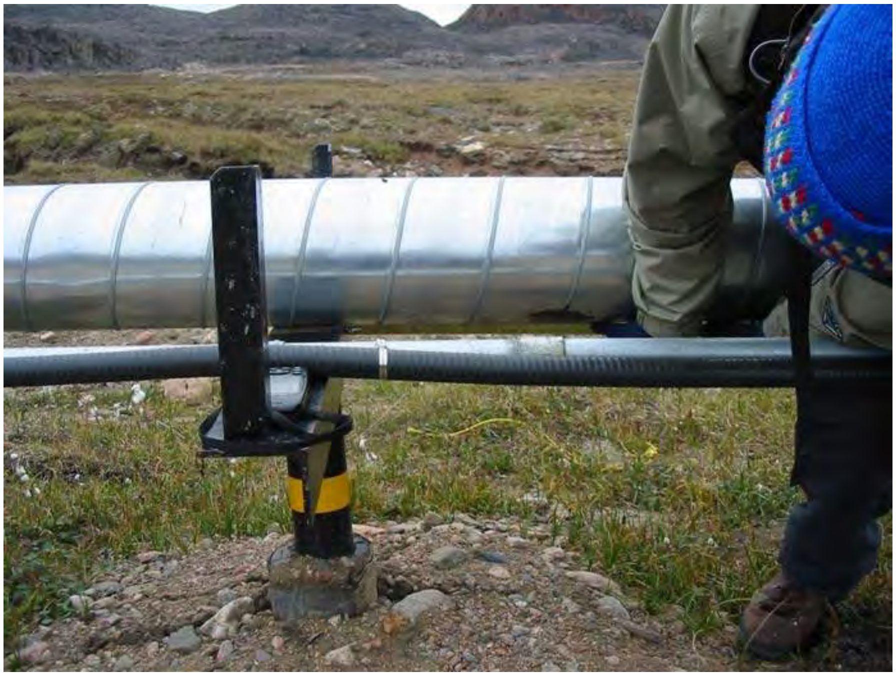
Photograph 18: Displacement downhill of the pipeline by approximately 14.5 inches at approximately 20 metres below the expansion loop.

Photograph 19: Approximately 180 metres downhill of expansion loop, displacement of approximately 14 inches.

Photograph 20: Approximately 235 metres downhill of expansion loop, displacement of approximately 15 inches.

Photograph 21: Approximately 265 metres downhill of expansion loop. A temporary cable restrain that has been installed into the junction box by the Hamlet.

Photograph 22: Approximately 310 metres below of expansion loop, displacement of approximately 15 inches.



Photograph 23: Approximately 60 metres above the road crossing, displacement of approximately 14 inches.

Photograph 24: 22 1/2º bend uphill of road crossing.

Photograph 25: At the road crossing. The pipe downstream from the bend was originally installed in a straight line but has buckled laterally approximately 20 inches.

Photograph 26: Bend due to buckling uphill of road crossing.

Photograph 27: Pipe has displaced laterally approximately 13 inches on the supports above the road crossing.

Photograph 28: Photograph is taken from the road looking down the pipeline. Note that the pipeline is straight to the next junction box but has some observable displacements beyond the junction box.

Photograph 29: Approximately 15 metres downhill of road crossing displacement of 3 inches.

Photograph 30: Approximately 65 metres downhill of road crossing displacement of approximately 5 inches down slope.

Photograph 31: Photograph depicts the lateral displacement of the pipeline below junction box no. 2.

Photograph 32: Upstream of the Truck Fill Station.

Initial Observations
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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April 2005

Table of Contents

Introduction

The following report of the initial observations following Trow's site visit to Cape Dorset. In this report we provide an initial summary of our field observations, an estimate of the potential displacement due to temperature change in the pipeline, summarize some concerns arising during our visit, and briefly report on features proposed for the 2004 stabilization program.

Field Observations

During the site visit to Cape Dorset, an inspection was conducted along the length of the pipeline. Measurements and photographs (included in Appendix A) were taken during the course of this inspection. Estimates of the displacement of the pipeline have been made based upon paint marks in the vicinity of the pipe supports. It is estimated that the pipeline has displaced downhill approximately 5 to 10 centimetres in the section of the pipe between the Heater House and the expansion loop. In the section below the expansion loop and above the road crossing, displacements of 30 to 40 centimetres were observed. For the section of the pipeline between the road crossing and the water storage, displacements of 7 to 20 centimetres were measured. These measurements seem to support the view that bending within the expansion loop has allowed the pipeline between the loop and the road crossing to move down slope by approximately 30 to 40 centimetres. Currently, restraints have been installed by Hamlet forces at the expansion loop and at junction boxes below the expansion loop. This is a reasonable temporary measure to restrain the pipeline, but the cables may not be capable of resisting the forces that may occur over the pending operating season.

Potential Displacement Estimates

An initial estimate of the potential displacement that could occur due to temperature changes of the water supply main has been developed. In preparing these estimates, two cases have been considered. The first case represents an estimate of the thermal expansion that would occur due to seasonal variations in temperature. For this estimate, it has been assumed that the ambient temperature would routinely swing from -40ºC to +20ºC over the annual period. The thermal displacement of stainless steel pipe over this temperature range is approximately 0.38 mm/m. Between the Heater House and the expansion loop this would represent more than 15 centimetres of displacement. Between the expansion loop and the road crossing a further 15 centimetres of displacement is anticipated. The second case, which has been considered, is thermal expansion that would arise due to the continuous operation of the heat trace cable. For this alternative, it has been assumed that the heat trace cable has been left in operation long enough that the only mechanism for dissipation of heat from the cable is conduction through the insulation. From information in the Operation and Maintenance Manual together with a heating cable tag recovered from the site, we have determined that the cable rating is 22 W/m. The initial calculations indicate that the internal temperature of the pipeline could rise as much as 100ºC above the ambient should sufficient time arise to achieve steady state conditions. This level of temperature change would cause thermal expansion of approximately 1.2 mm/m. This would represent a potential expansion of almost 60 centimetres between the Heater House and the expansion loop and a further expansion of approximately 55 centimetres between the expansion loop and the road crossing.

Conclusions

Based upon the preceding estimates, it is concluded that significant thermal movement can occur. Restraint to avoid thermal expansion is an undesirable in that high stress in the pipeline will arise bringing with it the risk of potential damage to the piping. Restraint at locations that are not tolerant to movement and provision of opportunity for movement at other locations is a preferable strategy. One specific location, which is intolerant of movement, is the Heater House near Tee Lake. Due to a lack of restraint down slope of the expansion loop, the loop is probably not completely effective in accommodating thermal expansion and contraction. Movement is currently being restrained at the pipeline road crossing, which has lead to buckling of the pipeline up slope of the road crossing. From these observations, provision of restraint at the heater building, restraint down slope of the expansion loop, removal of restraint at the road crossing and accommodation of movement down slope of the existing expansion loop should be incorporated into the pipeline.

There are logistical challenges for a program of improvements to this water supply pipeline. Regarding the construction of permanent measures, the required welding equipment and materials are not in Cape Dorset and these cannot be mobilized to the Community for use during the current construction season. Secondly, it is desirable that the necessary materials be acquired prior to the sailing of the last sealift vessel so that any necessary construction can be performed during the most favourable portion of the 2005 construction season. Thus, a program of stabilization of the pipeline in 2004 and the construction of more permanent measures in 2005 is the most appropriate course of action.

Proposed 2004 Temporary Stabilization Program

Based upon existing site conditions, the following strategy for the accommodation of pipeline rehabilitation was proposed:

1. Secure the pipeline in the vicinity of the Tee Lake Heater House to reduce the risk of excessive force upon the piping within the building.

2. Provide for movement of the pipeline below the heater building into the existing expansion loop.

3. Secure the lower leg of the expansion loop and pipeline below the loop to separate thermally induced displacements between those portions of the piping above and below the loop.

4. Carefully release the road crossing restraint and permit horizontal movement of the pipeline into the curved section of the pipeline.

5. Observe the over winter performance of the pipeline during the winter of 2004/2005.

Methods for providing permanent restraint of the piping as well as examining the need for further expansion loops will be evaluated. Potential locations for expansion loops include immediately uphill of the road crossing and some intermediary location between the Heater House and the existing expansion loop.

It is preferable that any mechanism used to restrain the pipeline be secured to the core pipe, but as has been noted above, welding to this pipeline is not possible at this time. Thus, a program of stabilization in 2004 with the intent of reducing the risk of further damage of the pipeline was the best effort that could be achieved within the available timeframe. Such a program carries the risks of a temporary solution, but short term measures were appropriate to reduce the risks over the pending winter.

The contractor had provided the detail, which was prepared by Dillon Consulting, of a clamp-on sleeve system to attach to the pipeline. It appeared to be a reasonable method to secure the pipeline in the short-term. This system does raise some questions as restraint is dependent upon the internal bond between the insulation, piping and exterior jacket, together with the friction between the clamp-on sleeves and the external jacket. It was also recognized that few other alternative existed for the winter of 2004/05.

It was proposed that four of these clamps be placed in proximity of the pump house to secure the upper portion of the pipeline. It was further proposed that four of these clamps be installed immediately downhill of the expansion loop. During the course of the installation of these clamps downstream of the expansion loop, it was recommended that effort be applied to attempt to return the pipeline to its original position prior to winter conditions. This would be followed by the careful removal of the restraint at the road crossing. In the area of the Heater House anchorage could be easily provided to bedrock. In the vicinity of the expansion loop the only anchorage immediately available are the existing pipe supports. Due to the size of these supports and depth of the active layer, the clamp on sleeves should be secured to several pipe supports. Due to uncertainty regarding the amount of friction with the clamping system it was proposed that the length of these clamps be increased to 1.5 metres. A sketch detailing these clamps was provided and included in Tab 8 – 2004 – Pipeline Stablization Program.

It is recommended that the contactor be directed to obtain ten (10) clamp-on sleeves together with the cable required to secure these sleeves.

Regarding operation of the pipeline, one specific concern relates to operating the heating cables for an excessive period of time. As was noted above, operation of these cables for a protracted period of time can cause sufficient temperature rise to cause large thermal expansions of the pipeline, which carry the risk of further unfavourable movement of the piping.

Appendix A
Photographic Field Record

Photograph No. 1: Inside Heater House

Photograph No. 2: View of pipeline from Tee Lake towards Heater House

Photograph 3: Immediately below the junction box, between the Heater House and Tee Lake. Photograph illustrates a displacement of approximately 1.5 inches.

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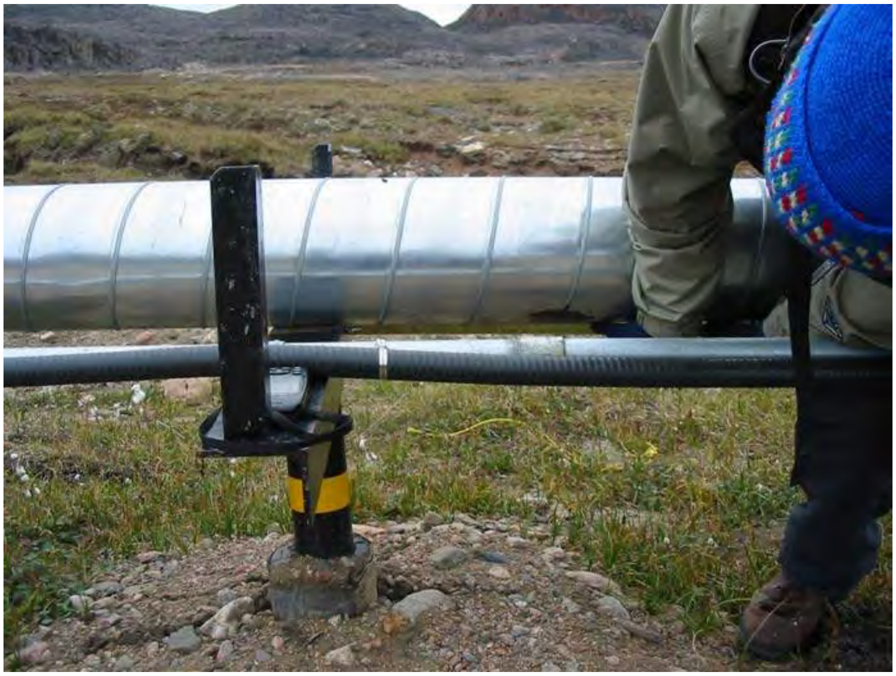

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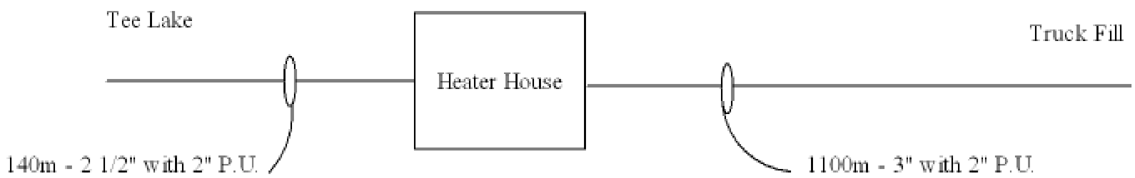
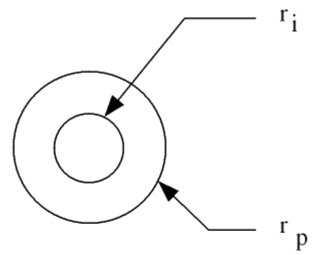
Cape Dorset
Thermal Computations

A) System Description



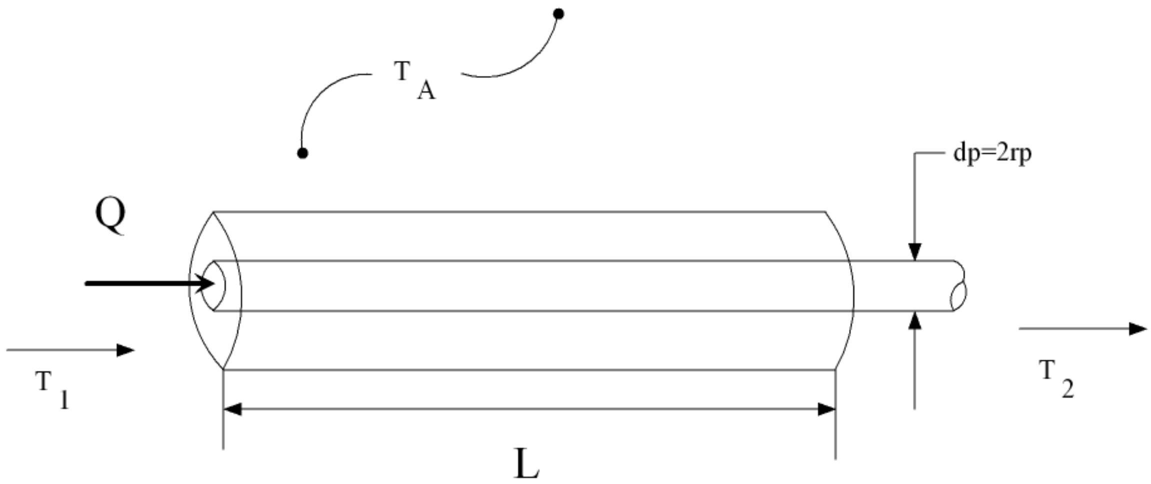


Pipe Size	Dimensions			
	r_p		r_i	
	in	mm	in	mm
2 ½"	2.875 / 2 = 1.438	36.5	1.438 + 2 = 3.438	87.3
3"	3.50 / 2 = 1.75	44.5	1.75 + 2 = 3.75	95.3

Installed Heat Trace

- MI Cable
- 600 V
- 70 m lengths
- 2.6 A
  → 22 w/m

B) Temperature Depression



D = Q*C*R.

$$R = \frac{\ell n\ (r_i/r_p)}{2\ k_i}$$

Q = 5 l/s = 0.005 m^3/s

k_i = 0.023 w/m °C

C = 4186 j/kg °C = 4.186 x 10^6 j/m^3 °C

For Tee Lake Heater House

$$R = \frac{\ell_n\ (87.3/36.5)}{2\Pi \times 0.023}$$

$= 6.03$

$D = Q * C * R$

$= .005 \times 4.486 \times 10^6 \times 6.03$

$= 126, 200$

For Input Temperature $T_1 = 4\ °C$
And Ambiant $T_A = -\ 50\ °C$

$T_2 = T_A + (T_1 – T_A) \exp (\ell/D)$

$$= -50 + (4 – (-50)) \exp \left(\frac{-140}{126, 200}\right)$$

$= 3.94\ °C$

For Heater House to Truck Fill

Without Heating

T_1 = 3.94 °C, T_A = -50 °C

$$R = \frac{\ell_n\ (95.3/44.3)}{2 \times \Pi \times .023}$$

= 5.27

D = Q x C x R

= 0.005 x 4.186 x 10^6 x 5.27

= 110, 300

$$T_2 = -50 + (3.94 - (-50)) \exp\left(\frac{-1100}{110,300}\right)$$

= 3.40 °C

With Heating On

For Heat Input = 60, 000 w (2x30 $k_{w)}$

= 60, 000 j/s

For 5 l/s mass flow = 5 kg/s

$$\triangle T = \frac{60,000 \text{ j/s}}{5 \text{ kg/s} \times 4/\ 86 \text{ j/kg °C}}$$

= 2.9 °C

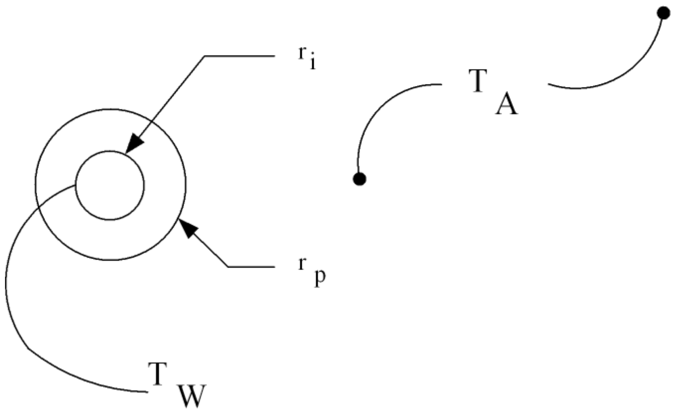
At Heater House T_{out} = T_{in} + 2.9 °C

Computations in Attached Spread Sheet Summarized as Follows

Ambiant	Tee Lake	Heater House		Truck Fill	Comments
		In	Out		
-50	4	3.94	3.94	3.40	
-50	0.5	0.44	0.44	-0.06	Heater OFF
-50	0.5	0.44	3.34	2.81	Heater ON
-30	4	3.96	3.96	3.63	
-30	0.5	0.47	0.47	0.16	Heater OFF
-30	0.5	0.47	3.37	3.03	Heater ON
-30	0.4	0.37	0.37	0.06	Test for lowest permissible T_1
-50	0.6	0.54	0.54	0.04	

Q	C	rp	ti	ri	k	R	G	L	T1	Ta	T2	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	4	-50	3.94	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.94	-50	3.4	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.5	-50	0.44	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.44	-50	-0.06	Heaters off
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.34	-50	2.81	Heaters on
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	4	-30	3.96	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.96	-30	3.63	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.5	-30	0.47	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.47	-30	0.16	Heaters off
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.37	-30	3.03	Heaters on
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.4	-30	0.37	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.37	-30	0.06	
											0.54	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.6	-50	0.04	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.54	-50		

C) Heat Loss Rate



$Q = (T_W - T_A) / R_I$

$R_I = \frac{\ell_n (ri/rp)}{2\Pi\ k_i}$

From Previous Calculations

For	2 ½ "	R = 6.03
	3"	R = 5.27

$\Delta T = T_W - T_A$

For 3" Ø For $T_A = -30$ and $T_W = 4$

$\Delta T = 34$

$Q = 34/5.27$

$= 6.5$ W/m

ΔT (°C)	Q (W/m)
10	1.9
20	3.8
30	5.7
40	7.6
50	9.5
60	11.3

Highest Potential Temperature

$$Q = \frac{(T_W - T_A)}{R_I}$$

From Previous Calculations

For 3" 0 $R_I = 5.27$

Following Long Term Steady State

Q = Heat Trace Input

Heat Trace Capacity = 22 w/m

At Steady State

$T_W - T_A = Q\ R_I$

= 22 x 5.27

= 116 °C

If Insulation Conductivity is 2x Manufactures Value (i.e. 0.046 w/m °C)

$$R_I = \frac{\ell_n\ (RI/RP)}{2\Pi \times 2\ k_i.}$$

$$R_I = \frac{\ell_n\ (95.3/44.5)}{2\Pi \times 0.046}$$

= 2.63

TW - TA = 22 x 2.63

= 58 °C

Based on Above – Long Term Steady state could place pipe temperature as high as 116 °C above ambient.

D) Thermal Expansion

1) Seasonal Variation

From Canadian normals

FEB – Mean Low - -29.2 °C - Extreme Low - -40.6 °C	JULY – Mean High - 11.2 °C - Extreme High - 25 °C

Due to effects of insulation mean low (FEB) to mean high (JULY) is likely seasonal swing.
i.e. 11.2 – (-29.2) = 40.4 °C OR 73 °F

For 316 Stainless Expansion Coeff = 0.000017 cm/cm °C

For L = 1, 100

Expansion = 1,100 x 100 x 0.000017 x 73
= 137 cm

2) Due to Heat Trace Continuous Operation

For 22 W/m input

May $T_W - T_A$ = 116 °C

If T_A = 0 -°C – i.e. early or late summer

$T_{internal}$ = 116 °C if empty

With flowing water internal temp goes to water temp.i.e. 5 °C
△T = 111 °C

Expansion = 1100 x 100 x 0.000017 x 111
= 208 cm

If Ta = -40°C

$T_{Internal}$ = 76°C – Pipe empty
T_{In} = 0°C - Pipe full
Δ T = 76°C
Expansion = 1100 x 100 x .000017x76 = 142 cm

Summary
For 1100 m length
Seasonal variation ~ 140 cm
Operating variation is between 140 and 210 cm

E) Summary

1. Temperature Depression

   During winter
   With heaters on, arriving temperature at truck fill ≈ 3°C

   During winter with - 30°C
   Ambient and heater off water arrives near freezing

2. Heat Loss

   For temperature difference between water and ambient less than 50°C
   Heat loss ≤ 10 w/m

   Heat trace installed capacity = 22 w/m

3. Highest potential temperature is 116°C above ambient

4. Thermal Expansion

   For 1,100 m
   Seasonal variation ≈ 140 cm
   Operational variation during fill cycle between 140 and 210 cm

5. Installed heat trace capability

   = 22 w/m
   Next size thermon cable provides
   11.2 w/m
   Stipulated requirement = 11.8 w/m

Environment Canada Environnement Canada

Canadian Climate Normals 1971-2000

The minimum number of years used to calculate these Normals is indicated by a code for each element. A "+" beside an extreme date indicates that this date is the first occurrence of the extreme value. Values and dates in bold indicate all-time extremes for the location.

NOTE!! Data used in the calculation of these Normals may be subject to further quality assurance checks. This may result in minor changes to some values presented here.

CAPE DORSET A
NUNAVUT

Latitude: 64° 13' N **Longitude:** 76° 31' W **Elevation:** 50.00 m

Climate ID: 2400635 **WMO ID:** 71910 **TC ID:** YTE

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-25.0	-26.0	-21.6	-14.1	-5.5	2.3	7.4	5.7	1.5	-3.9	-11.7	-20.2	-9.3	D
Standard Deviation	3.3	2.8	2.8	2.0	1.8	1.4	1.2	1.3	1.2	1.5	2.7	4.0	5.4	D
Daily Maximum (°C)	-21.7	-22.7	-17.9	-10.3	-2.7	5.1	11.2	8.8	3.6	-1.8	-8.7	-16.9	-6.2	D
Daily Minimum (°C)	-28.3	-29.2	-25.1	-18.0	-8.3	-0.6	3.5	2.5	-0.7	-5.9	-14.8	-23.4	-12.4	D
Extreme Maximum (°C)	-1.4	-1.5	0.8	5.6	10.9	17.9	**25.0**	21.9	18.1	7.2	3.4	-0.8		
Date (yyyy/dd)	1985/18	1986/27	1999/28	1975/29+	1993/31	1985/15	**1984/15**	1991/09	1989/10	1998/02	1985/02	1998/05+		
Extreme Minimum (°C)	-38.9	-40.6	-42.2	-32.8	-19.6	-9.3	-3.4	-4.6	-8.3	-23.9	-30.6	**-42.8**		
Date (yyyy/dd)	1964/14	1964/26	1964/11	1963/01	1983/15	2000/04	1983/11	1983/23	1963/30+	1986/25	1963/28	**1971/30**		
Precipitation:														
Rainfall (mm)	0.0	0.0	0.0	0.1	3.1	14.7	34.4	54.7	32.5	4.3	0.0	0.0	143.9	D
Snowfall (cm)	25.5	20.4	25.7	34.6	30.7	9.3	0.4	1.4	14.1	42.8	50.2	41.5	296.4	D
Precipitation (mm)	22.3	17.3	21.8	30.1	31.1	23.7	34.4	56.0	46.7	44.3	42.4	33.1	403.0	D
Average Snow Depth (cm)	48	46	52	59	56	19	0	0	0	6	22	36	29	D
Median Snow Depth (cm)	49	46	52	57	57	18	0	0	0	6	21	36	29	D
Snow Depth at Month-end (cm)	48	47	55	58	41	1	0	0	1	13	28	40	28	D
Extreme Daily Rainfall (mm)	0.0	0.0	0.0	1.2	11.4	35.2	24.8	**41.2**	32.0	17.3	0.6	0.2		
Date (yyyy/dd)	1964/01+	1963/01+	1963/01+	2001/30	1980/30	2001/17	1995/02	**1986/20**	1998/10	1973/11	1985/02	1998/04		
Extreme Daily Snowfall (cm)	29.7	20.3	13.6	23.0	19.0	15.6	2.6	9.2	19.6	20.2	25.7	15.7		

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Date (yyyy/dd)	1971/28	1964/02	1990/09	1995/09	1991/23	2001/17	1995/02	1986/20	1998/10	1999/31	1970/23	1971/05		
Extreme Snow Depth (cm)	127.0	84.0	88.0	147.0	94.0	90.0	3.0	0.0	18.0	36.0	74.0	92.0		
Date (yyyy/dd)	1975/13+	2001/26+	2001/26+	1975/02+	1983/24	1987/03	1992/01	1971/01+	1992/24	1974/29+	1989/28+	1993/20+		
Days with Maximum Temperature:														
<= 0 °C	31.0	28.3	30.8	29.2	23.8	2.4	0.0	0.0	3.8	23.0	29.1	31.0	232.3	D
> 0 °C	0.0	0.0	0.24	0.77	7.2	27.6	31.0	31.0	26.2	8.1	0.94	0.0	133.0	D
> 10 °C	0.0	0.0	0.0	0.0	0.06	4.2	18.1	10.4	1.0	0.0	0.0	0.0	33.7	D
> 20 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.41	0.09	0.0	0.0	0.0	0.0	0.50	D
> 30 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	D
> 35 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	D
Days with Minimum Temperature:														
> 0 °C	0.0	0.0	0.0	0.0	0.23	10.2	27.9	26.4	11.1	0.42	0.0	0.0	76.3	C
<= 2 °C	29.8	27.3	30.0	28.5	29.1	24.7	9.7	13.3	25.1	29.3	28.6	28.7	304.2	C
<= 0 °C	29.8	27.3	30.0	28.5	28.9	18.5	1.3	3.0	17.2	28.9	28.6	28.7	270.8	C
< -2 °C	29.8	27.3	29.9	28.3	26.8	7.2	0.10	0.16	7.5	25.7	28.4	28.7	239.9	C
< -10 °C	29.8	27.3	29.3	24.6	9.6	0.0	0.0	0.0	0.0	3.5	21.2	27.6	173.0	C
< -20 °C	27.1	25.7	24.1	10.6	0.0	0.0	0.0	0.0	0.0	0.08	5.4	20.1	113.0	C
< - 30 °C	12.2	13.1	5.8	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	36.3	C
Days with Rainfall:														
>= 0.2 mm	0.0	0.0	0.0	0.25	1.8	6.1	11.6	12.6	10.1	2.2	0.05	0.05	44.7	C

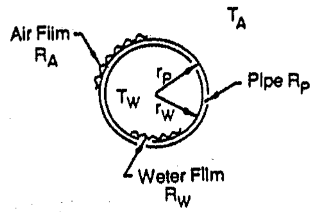
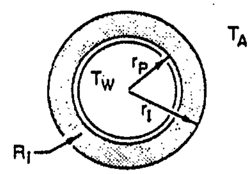
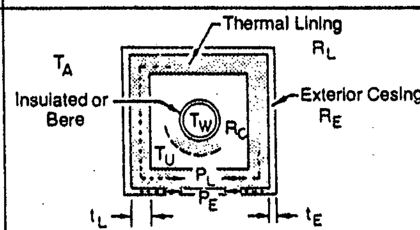
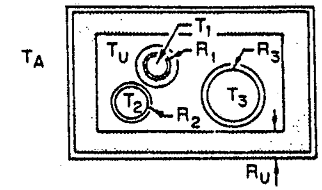
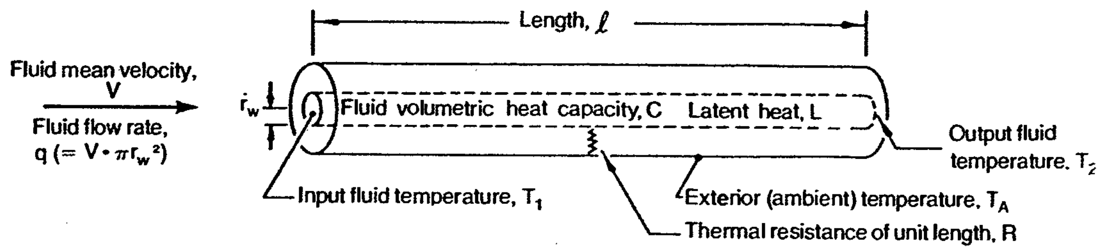
	(a) Bare Pipe	(b) Insulated Pipe	(c) Single Pipe in a Box	(d) Multiple Pipe Utilidor
Sketch				
Assumptions	Thinwelled pipe (i.e. $r_P \approx 2\, r_W$). R_W is negligible. $R_P \approx R_A$.	All thermal resistances but thet of the insuletion ere neglected.	Convection ensures the temperature inside the utilidor, T_U, is uniform. Utilidor eir films neglected.	Same es (c).
Thermal Resistance	$R_P = (r_P - r_W)/(r_P + r_W)\ \pi\ k_P$ $h_A = N \left(\frac{T_W - T_A}{r_P}\right)^{0.25} W$ $R_A = 1/2\pi r_P h_A$ $R_C = R_P + R_A$ $N = 0.23\ \mathrm{Btu/h \cdot ft^{\frac{7}{4}} \cdot {}^\circ F^{\frac{5}{4}}}$ $W = \sqrt{12.5V + 1}$ for V = miles/h $N = 1.12\ \mathrm{J/s \cdot m^{\frac{7}{4}} \cdot {}^\circ C^{\frac{5}{4}}}$ $W = \sqrt{0.56V + 1}$ for V = m/s	$R_C = R_I = \frac{\ln(r_I/r_P)}{2\pi k_I}$ $\approx \left(\frac{r_I - r_P}{r_I + r_P}\right) / \pi k_I$ if $r_I \approx 2 r_P$ Or given r_I/r_P end k_I; reed off R_I from graph	Calculate R_C, the thermal resistance of the interior conduit by: using (b) if insulated or using (e) if bere and replacing T_A in the formule for h_A by an estimate for T_U ($\le T_W$) $R_L = t_L/P_L k_L$ $R_E = t_E/P_E k_E$ $R_U = R_L + R_E$ $R = R_C + R_U$ $T_U = \frac{(T_W/R_C) + (T_A/R_U)}{(1/R_C) + (1/R_U)}$ If bere pipe, iterate T_U	Calculate R for each pipe as in (c) to get R_J, (J= 1, 2, 3, . . .). Celculete R_U es in (c) $T_U = \frac{\sum_J (T_J/R_J) + (T_A/R_U)}{\sum_J (1/R_J) + (1/R_U)}$ If bere pipes present, iterete T_U
Rate of Heat Loss	$Q = (T_W - T_A)/R_C$	$Q = (T_W - T_A)/R_I$	$Q = (T_W - T_A)/R$	$Q_J = (T_J - T_U)/R_J$ (per pipe) $Q = \sum_J Q_J = (T_U - T_A)/R_U$
Insulation Thickness (given Q)	N/A	$r_I - r_P = r_P\{\exp[2\pi k_I (T_W - T_A)/Q] - 1\}$ $\approx \pi k_I (T_W - T_A) Q$ if $r_I \approx 2 r_P$ Or given R_I end k_I; reed off r_I/r_P from graph	Obtein R_E end R_C es ebove $t_U = P_L k_L \left[\frac{(T_W - T_A)}{Q} - R_E - R_C\right]$ If bere interior pipe, iterate T_U, R_C end hence t_L	Given ecceptable Q_J, celculate R_J as above and evaluate $T_U = T_J - R_J Q_J$ **for each pipe for which Q_J is known.** Using the meximum T_U found, calculete new Q_J as above. Using these Q_J end the same T_U, eveluate $t_L = R_L k_L \left[\frac{T_U - T_A}{\Sigma Q_J} - R_E\right]$ If bere pipes present, iterete T_U, R_J and hence t_L
Comments	Often, for metel pipes, R_P mey be neglected. If R_P is significent, the expression ebove for h_A will generete an overestimate of Q. If $T_A > T_W$ switch T_A end T_W in the expression for h_A.	The neglected thermel resistences given in (a) mey be included if desired. Estimate a value for the insuletion surfece temperature and calculete h_A and R_A. Interate.	The velue of h_A, and hence R_A, is feirly insensitive to the choice of T_U, end so one itereton on T_U is usually sufficient. Often R_E may be neglected. Similer celculational procedure may be performed for pipes and utilidors of different cross-section.	es (c). If it is cleer that one pipe dominetes the heat loss process, (c) may be used to estimate T_U. It is wise to consider the heat loss from the verious pipes if certain other pipes ceese to function.

FIGURE 15-10. STEADY-STATE THERMAL EQUATIONS FOR ABOVE-SURFACE PIPES [adapted from 82]

Heat Loss and Temperature Drop in a Fluid Flowing Through a Pipe	Freeze-Up Time For a Full Pipe Under No-Flow Conditions (V = c



Comments: The above sketch is schematic. R and T_A appearing in these equations can be replaced by the thermal resistance and corresponding exterior temperature for any shape or configuration.

$D = \pi r_w^2 \, V \cdot C \cdot R$

Calculate T_1 or T_2, Given R, T_1 or T_2, T_A

$T_1 = T_A + (T_2 - T_A) / \exp(-\ell/D)$

$\approx T_A + (T_2 - T_A)/(1 + \ell/D) \quad \text{if } \ell/D \lesssim 0.1$

$T_2 = T_A + (T_1 - T_A)\exp(-\ell/D)$

Calculate R, Given T_1, T_2, T_A

$R = \ell / \pi r_w^2 \cdot V \cdot C \cdot \ln[(T_2 - T_A)/(T_1 - T_A)]$

$\approx \ell(T_1 - T_A)/\pi r_w^2 \cdot V \cdot C\,(T_1 - T_2) \text{ if } \ell/D \lesssim 0.1$

Calculate V, Given T_1, T_2, T_A, R

$V = \ell / \pi r_w^2 \cdot R \cdot C \cdot \ln[(T_2 - T_1)/(T_1 - T_A)]$

$\approx \ell(T_1 - T_A)/\pi r_w^2 \cdot V \cdot C(T_1 - T_2) \quad \text{if } \ell/D \lesssim 0.1$

Calculate Heat Loss (Q), Given T_1 or T_2, T_A, V, R

$Q = (D/R)(T_1 - T_A)[1 - \exp(-\ell/D)]$

$\approx (\ell/R)(T_1 - T_A) \quad \text{for } \ell/D \lesssim 0.1$

$= D/R\,(T_2 - T_A)\left[\exp(\ell/D) - 1\right]$

Calculate Friction Heating, Given V, f

$Q_f = F \cdot r_w^2 \cdot V \cdot f$

Where: Q_f = BTU / h · ft
F = 0.2515 BTU / ft⁴
r = ft
V = ft / h
f = friction head loss, ft / ft length
Not significant for $V \lesssim 2.3 \times 10^4$ ft / h

or Q_f = J / s · m
$F = 3.074 \times 10^4$ J / m⁴
r = m
V = m / s
f = friction head loss, m / m length
Not significant for $V \lesssim 2$ m · s

Freeze-Up Times; Given R, T_1, T_A

Assume that thermal resistance of the ice, as it forms, and the heat capacity of the pipe and insulation are negligible.

Design Time (Recommended)

t_D = Time for the fluid temperature to drop to the freezing point.

$= \pi \cdot r_w^2 \cdot R \cdot C \cdot \ln[(T_1 - T_A)/(T_O - T_A)]$

$= \pi \cdot r_w^2 \cdot R \cdot C\,[(T_1 - T_O)/(T_1 - T_A)]$

for $[(T_1 - T_O)/(T_1 - T_A)] \leq 0.$

or $T_1 \lesssim 0.11\,T_A$ (in °C)

Safety Factor Time

t_{SF} = Time for the fluid to drop to the nucleation temperature. Same as t_D but with T_O replaced by −3°C.

Complete Freezing Time

t_F = Time for the fluid at freezing point, 0°C, to completely freeze solid.

$= \pi \cdot r_w^2 \cdot R \cdot L / (T_O - T_A)$

Calculate R, Given a No-Flow Time

Design Choice

$R_D = \text{time} / \pi \cdot r_w^2 \cdot C \cdot \ln[(T_1 - T_A)/(T_O - T_A)]$

Minimum Resistance

R_{SF} = same as R_D but with T_O replaced by −3°C.

FIGURE 15-13. TEMPERATURE DROP AND FREEZE-UP TIME IN PIPES [adapted from 82]

Selected Cable

For MQ – 10E14 – 2S
1 Ω/ft
70 m →230 ft→230 Ω

At 600 V; I = 600/230 = 2.6 A
P=IV= 600 x 2.6
= 1565 w or $\frac{V^2}{R} = \frac{600^2}{230}$

Or 22 w/m

Other Cables

MIQ – 70 E2H – 2S
-0.7 Ω/ft
For 70 m→ 161 Ω
P= $\frac{Y^2}{R} = \frac{600^2}{161}$ =2,236 or
32 w/m
For M1Q – 20 E1H – 2S
2.0 Ω/ft
70 m → 230 ft →460Ω
600 Volts

P= $\frac{V^2}{R} = \frac{600^2}{460}$ =11.2 w/m

Requested cable capacity = 11.8 w/m

MIQ™
Mineral Insulated Cable

Product Specifications

Application . . .

Process Temperature Maintenance or Freeze Protection
MIQ high performance mineral insulated heating cables are used extensively for high temperature maintenance, high temperature exposure and/or high watt density applications which exceed the limitations of thermoplastic insulated cables. The resistance configurations available can provide tracing for pipes up to 1 mile (1.6 km) long from a single power supply point.

Thermon's MIQ mineral insulated cables are manufactured using Alloy 825, a high nickel/chromium alloy ideally suited for high temperature service that offers exceptional resistance to stress corrosion in chloride, acid, salt and alkaline environments.

MIQ cables are approved for use in ordinary (nonclassified) areas, hazardous (classified) areas, and Zone 1 and 2 classified areas.

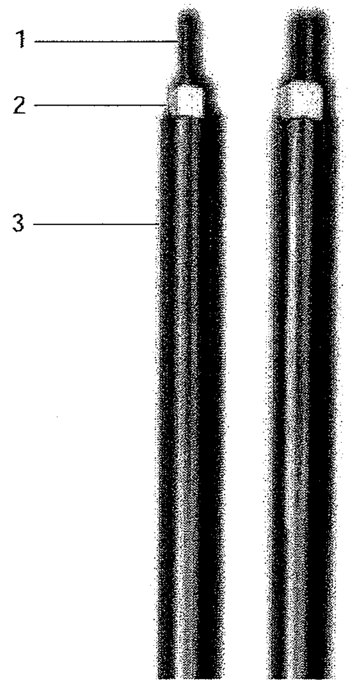
Ratings . . .

Rated voltage[1]	300 and 600 Vac
Max. maintenance temperature[2]	932°F (500°C)
Max. continuous exposure temperature	
Power-off	1,100°F (593°C)
Max. watt density[2]	up to 80 w/ft (262 w/m)
Minimum bend radius	6 x cable O.D.

MIQ Heater Sets . . .

Thermon MIQ cable sets are available in four factory fabricated configurations: Type A, B, D or E. The standard assemblies consist of a predetermined length of heating cable joined to a standard[3] 4' (1,220 mm) nonheating cold lead with 8" (203 mm) long thermoplastic insulated pigtails.

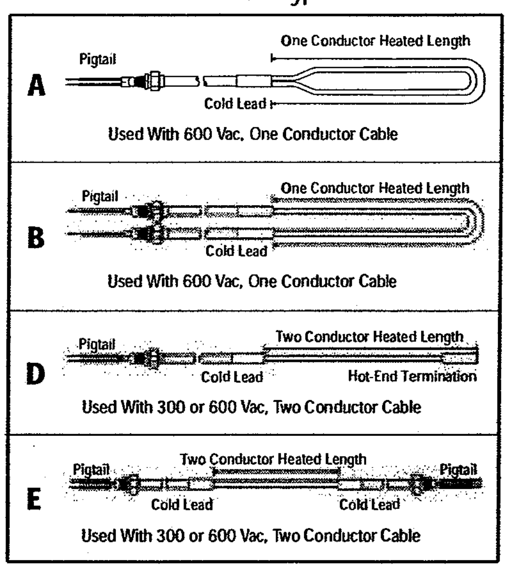
The nonheating section of the unit is sealed and fitted with a high pressure, liquid-tight 1/2" or 3/4" NPT stainless steel gland[4] for connection into the supply junction box.



Construction . . .

1 Solid Alloy or Copper Conductor(s)
2 Compacted Magnesium Oxide Insulation
3 Seamless Alloy 825 Sheath

Heater Set Types



Notes . . .

1. Definition as stated in IEEE Standard 515-1997. Specific voltage depends on circuit length and design conditions.
2. Watt density limitations are correlated to maintain temperatures. Maximum watt density for CSA certified application is 50 w/ft (164 w/m).
3. Cold lead will be sized for the circuit operating current in accordance with relevant NEC or CEC code requirements.
4. Cold lead gland is ½" NPT except for 2-conductor sets with larger wire sizes for which a ¾" NPT gland is provided.

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MIQ™
Mineral Insulated Cable

INSTALLED CABLE -70M LONG. SEE REVERSE

Product Specifications

Available MIQ Cables[1] . . .

600 Vac Cable—Two Conductor—Heater Set Type D or E

Catalog Number	Resistance[2] ohms/ft	Resistance[2] ohms/m	Nominal Diameter in	Nominal Diameter mm
MIQ-11EOH-2S	11.0	36.1	0.215	5.46
MIQ-90E1H-2S	9.0	29.5	0.230	5.84
MIQ-60E1H-2S	6.0	19.7	0.230	5.84
MIQ-40E1H-2S	4.0	13.1	0.235	5.97
MIQ-20E1H-2S	2.0	6.56	0.270	6.86
MIQ-10E1H-2S	1.0	3.28	0.255	6.48
MIQ-70E2H-2S	0.70	2.30	0.265	6.73
MIQ-50E2H-2S	0.50	1.64	0.280	7.11
MIQ-30E2H-2S	0.30	0.98	0.307	7.80
MIQ-20E2H-2S	0.20	0.66	0.255	6.48
MIQ-15E2H-2S	0.15	0.49	0.265	6.73
MIQ-10E2H-2S	0.10	0.33	0.280	7.11
MIQ-70E3H-2S	0.070	0.23	0.295	7.49
MIQ-50E3H-2S	0.050	0.16	0.312	7.92
MIQ-40E3H-2S	0.040	0.13	0.325	8.26
MIQ-30E3H-2S	0.030	0.098	0.350	8.89
MIQ-20E3H-2S	0.020	0.066	0.275	6.99
MIQ-16E3H-2S	0.016	0.052	0.285	7.24
MIQ-13E3H-2S	0.013	0.043	0.295	7.49
MIQ-10E3H-2S	0.0104	0.0341	0.307	7.80

INSTALLED

600 Vac Cable—One Conductor—Heater Set Type A or B

Catalog Number	Resistance[2] ohms/ft	Resistance[2] ohms/m	Nominal Diameter in	Nominal Diameter mm
MIQ-20E1H-1S	2.0	6.56	0.170	4.32
MIQ-16E1H-1S	1.6	5.25	0.170	4.32
MIQ-13E1H-1S	1.3	4.26	0.170	4.32
MIQ-10E1H-1S	1.0	3.28	0.170	4.32
MIQ-85E2H-1S	0.85	2.79	0.170	4.32
MIQ-70E2H-1S	0.70	2.30	0.170	4.32
MIQ-50E2H-1S	0.50	1.64	0.170	4.32
MIQ-38E2H-1S	0.38	1.25	0.170	4.32
MIQ-30E2H-1S	0.30	0.98	0.170	4.32
MIQ-25E2H-1S	0.25	0.82	0.170	4.32
MIQ-20E2H-1S	0.20	0.66	0.175	4.45
MIQ-17E2H-1S	0.17	0.56	0.180	4.57
MIQ-15E2H-1S	0.15	0.49	0.170	4.32
MIQ-10E2H-1S	0.10	0.33	0.170	4.32
MIQ-80E3H-1S	0.080	0.26	0.170	4.32
MIQ-70E3H-1S	0.070	0.23	0.170	4.32
MIQ-60E3H-1S	0.060	0.20	0.170	4.32
MIQ-40E3H-1S	0.040	0.13	0.180	4.57
MIQ-30E3H-1S	0.030	0.098	0.185	4.70
MIQ-20E3H-1S	0.020	0.066	0.200	5.08
MIQ-10E3H-1S	0.010	0.03395	0.170	4.32
MIQ-65E4H-1S	0.00651	0.02135	0.180	4.57
MIQ-40E4H-1S	0.00409	0.01342	0.195	4.95
MIQ-25E4H-1S	0.00258	0.00846	0.210	5.33
MIQ-16E4H-1S	0.00162	0.00531	0.240	6.10

300 Vac Cable—Two Conductor—Heater Set Type D or E

Catalog Number	Resistance[2] ohms/ft	Resistance[2] ohms/m	Nominal Diameter in	Nominal Diameter mm
MIQ-11E0L-2S	11.0	36.1	0.160	4.06
MIQ-90E1L-2S	9.0	29.5	0.160	4.06
MIQ-75E1L-2S	7.5	24.6	0.160	4.06
MIQ-60E1L-2S	6.0	19.7	0.160	4.06
MIQ-50E1L-2S	5.0	16.4	0.160	4.06
MIQ-40E1L-2S	4.0	13.1	0.160	4.06
MIQ-32E1L-2S	3.20	10.5	0.160	4.06
MIQ-27E1L-2S	2.75	9.02	0.160	4.06
MIQ-25E1L-2S	2.50	8.20	0.160	4.06
MIQ-20E1L-2S	2.00	6.56	0.160	4.06
MIQ-17E1L-2S	1.70	5.58	0.160	4.06
MIQ-14E1L-2S	1.40	4.59	0.160	4.06
MIQ-10E1L-2S	1.00	3.28	0.170	4.32
MIQ-70E2L-2S	0.70	2.30	0.180	4.57
MIQ-50E2L-2S	0.50	1.64	0.195	4.95
MIQ-30E2L-2S	0.30	0.98	0.170	4.32
MIQ-25E2L-2S	0.25	0.82	0.170	4.32
MIQ-20E2L-2S	0.20	0.66	0.170	4.32
MIQ-15E2L-2S	0.15	0.49	0.175	4.45
MIQ-10E2L-2S	0.10	0.33	0.195	4.95
MIQ-70E3L-2S	0.070	0.23	0.210	5.33
MIQ-50E3L-2S	0.050	0.16	0.230	5.84

Circuit Breaker Sizing and Type . . .

Breaker sizing should be based on the National Electrical Code, Canadian Electrical Code or any other applicable code.

The National Electrical Code and Canadian Electrical Code require ground-fault protection of equipment for each branch circuit supplying electric heating equipment. Check local codes for ground-fault protection requirements.

Certifications/Approvals . . .

Factory Mutual Research
Ordinary Locations
Hazardous (Classified) Locations
- Class I, Division 1 Groups B, C and D
- Class I, Division 2, Groups A, B, C and D
- Class II, Divisions 1 and 2 Groups E, F and G
- Class III, Divisions 1 and 2
- Class I, Zone 1, Group IIB + H_2
- Class I, Zone 2, Group IIC

Canadian Standards Association
Ordinary Locations
Hazardous (Classified) Locations
- Class I, Division 1 Groups B, C and D
- Class I, Division 2, Groups A, B, C and D
- Class II, Divisions 1 and 2, Groups E, F and G
- Class I, Zone 1, Group IIB + H_2
- Class I, Zone 2, Group IIC

Notes . . .

1. Other resistances are available. Contact Thermon for design assistance.
2. All resistances shown are per length of cable at 68°F (20°C) and are subject to a ±10% manufacturing tolerance.

Thermal Computations
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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Table of Contents

Introduction

Trow Associates Inc. undertook a detailed review of the thermal issues relating to the Cape Dorset water supply main. Issues included in the review included:

1. Estimate the heat loss under extreme conditions.
2. Determine the sensitivity to variability and deterioration of insulation.
3. Compare calculated heat loss with the selected heating cable system
4. Estimate the amount of thermal expansion.

Thermal calculations for the water supply pipeline have been prepared and are attached.

Summary of Findings

The following are the principle findings of the thermal calculations (included in Appendix A):

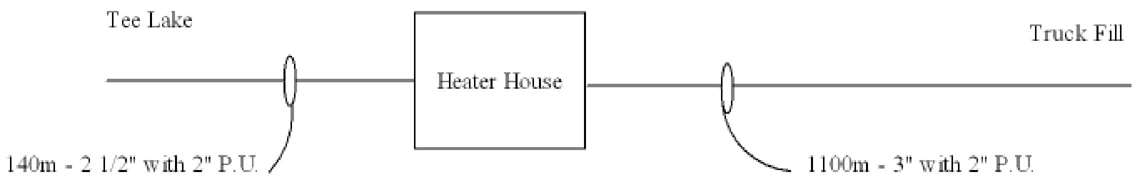
- During winter conditions (-30°C ambient) water should arrive at the Truck Fill Station at approximately 3°C if the immersion heaters are in operation. The arriving temperature is close to the freezing point if the heaters are not in operation.
- For a temperature difference across the insulation system of 50°C, heat loss is less that 10W/m. The installed heat trace capacity is 22W/m.
- Continuous operation of the present heat trace cable could raise the temperature 116°C above ambient if sufficient time past to establish steady state conditions.
- Thermal expansion along the 1,100 metre stainless steel pipeline is between 140 centimetres and 210 centimetre due to seasonal and operating variations in temperature.

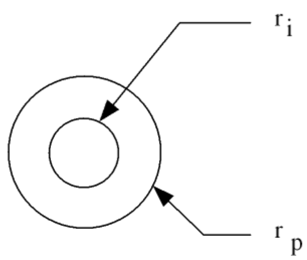
Appendix A:
Thermal Computations

A) System Description
B) Temperature Depression
C) Heat Loss Rate
D) Thermal Expansion
E) Summary

Cape Dorset
Thermal Computations

A) System Description



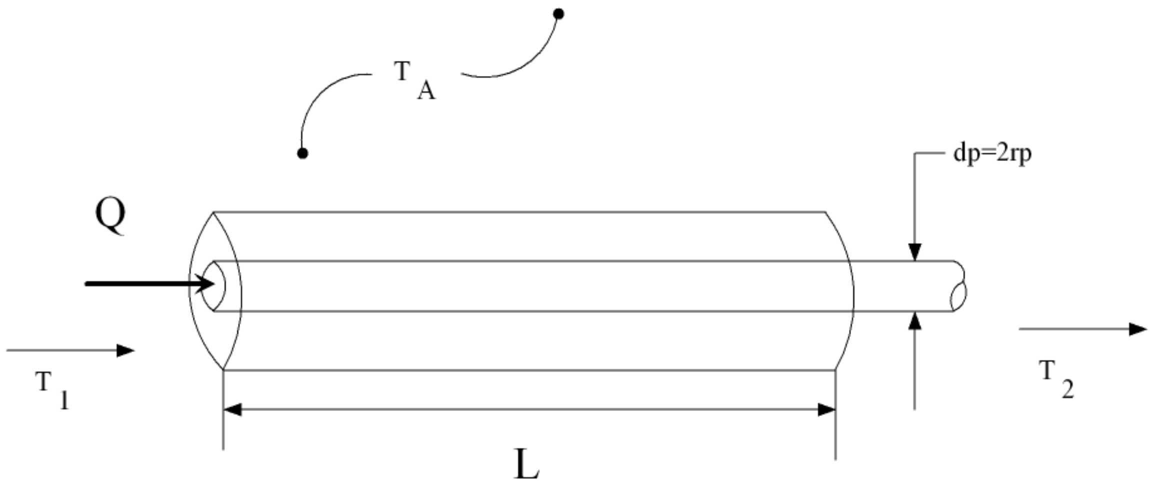


Pipe Size	Dimensions			
	r_p		r_i	
	in	mm	in	mm
2 ½"	2.875 / 2 = 1.438	36.5	1.438 + 2 = 3.438	87.3
3"	3.50 / 2 = 1.75	44.5	1.75 + 2 = 3.75	95.3

Installed Heat Trace

- MI Cable
- 600 V
- 70 m lengths
- 2.6 A
  → 22 w/m

B) Temperature Depression



D = Q*C*R.

$$R = \frac{\ell n\ (r_i/r_p)}{2\ k_i}$$

Q = 5 l/s = 0.005 m^3/s

k_i = 0.023 w/m °C

C = 4186 j/kg °C = 4.186 x 10^6 j/m^3 °C

For Tee Lake Heater House

$$R = \frac{\ell_n\ (87.3/36.5)}{2\Pi \times 0.023}$$

$$= 6.03$$

$$D = Q * C * R$$

$$= .005 \times 4.486 \times 10^6 \times 6.03$$

$$= 126,200$$

For Input Temperature $T_1 = 4\ °C$
And Ambiant $T_A = -50\ °C$

$$T_2 = T_A + (T_1 - T_A) \exp(\ell/D)$$

$$= -50 + (4 - (-50)) \exp\left(\frac{-140}{126,200}\right)$$

$$= 3.94\ °C$$

For Heater House to Truck Fill

Without Heating

T_1 = 3.94 °C, T_A = -50 °C

$$R = \frac{\ell_n\ (95.3/44.3)}{2 \times \Pi \times .023}$$

= 5.27

D = Q x C x R

= 0.005 x 4.186 x 10^6 x 5.27

= 110, 300

$$T_2 = -50 + (3.94 - (-50)) \exp\left(\frac{-1100}{110,\ 300}\right)$$

= 3.40 °C

With Heating On

For Heat Input = 60, 000 w (2x30 $k_{w)}$

= 60, 000 j/s

For 5 l/s mass flow = 5 kg/s

$$\triangle T = \frac{60{,}000\ j/s}{5\ kg/s \times 4/\ 86\ j/kg\ °C}$$

= 2.9 °C

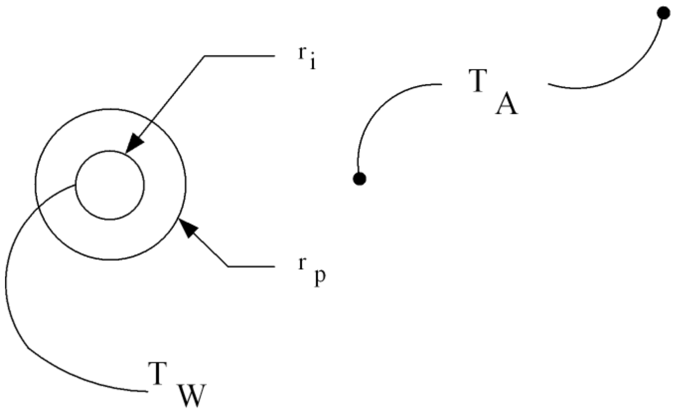
At Heater House T_{out} = T_{in} + 2.9 °C

Computations in Attached Spread Sheet Summarized as Follows

Ambiant	Tee Lake	Heater House		Truck Fill	Comments
		In	Out		
-50	4	3.94	3.94	3.40	
-50	0.5	0.44	0.44	-0.06	Heater OFF
-50	0.5	0.44	3.34	2.81	Heater ON
-30	4	3.96	3.96	3.63	
-30	0.5	0.47	0.47	0.16	Heater OFF
-30	0.5	0.47	3.37	3.03	Heater ON
-30	0.4	0.37	0.37	0.06	Test for lowest permissible T_1
-50	0.6	0.54	0.54	0.04	

Q	C	rp	ti	ri	k	R	G	L	T1	Ta	T2	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	4	-50	3.94	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.94	-50	3.4	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.5	-50	0.44	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.44	-50	-0.06	Heaters off
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.34	-50	2.81	Heaters on
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	4	-30	3.96	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.96	-30	3.63	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.5	-30	0.47	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.47	-30	0.16	Heaters off
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	3.37	-30	3.03	Heaters on
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.4	-30	0.37	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.37	-30	0.06	
											0.54	
0.005	4184000	36.5	50 Nominal	87.3	0.023	6.034	126238	140	0.6	-50	0.04	
0.005	4184000	44.5	50 Nominal	95.3	0.023	5.270	110242	1100	0.54	-50		

C) Heat Loss Rate



$Q = (T_W - T_A) / R_I$

$$R_I = \frac{\ell_n (ri/rp)}{2\Pi\ k_i}$$

From Previous Calculations

For	2 ½ "	R = 6.03
	3"	R = 5.27

$\triangle T = T_W - T_A$

For 3" Ø For $T_A = -30$ and $T_W = 4$

$\triangle T = 34$

$Q = 34/5.27$

$= 6.5$ W/m

△T (°C)	Q (W/m)
10	1.9
20	3.8
30	5.7
40	7.6
50	9.5
60	11.3

Highest Potential Temperature

$$Q = \frac{(T_W - T_A)}{R_I}$$

From Previous Calculations

For 3" 0 $R_I = 5.27$

Following Long Term Steady State

Q = Heat Trace Input

Heat Trace Capacity = 22 w/m

At Steady State

$T_W - T_A = Q\ R_I$

$= 22 \times 5.27$

$= 116$ °C

If Insulation Conductivity is 2x Manufactures Value (i.e. 0.046 w/m °C)

$$R_I = \frac{\ell_n\ (RI/RP)}{2\Pi \times 2\ k_i.}$$

$$R_I = \frac{\ell_n\ (95.3/44.5)}{2\Pi \times 0.046}$$

= 2.63

TW - TA = 22 x 2.63

= 58 °C

Based on Above – Long Term Steady state could place pipe temperature as high as 116 °C above ambient.

D) Thermal Expansion

1) Seasonal Variation

From Canadian normals

FEB – Mean Low - -29.2 °C - Extreme Low - -40.6 °C	JULY – Mean High - 11.2 °C - Extreme High - 25 °C

Due to effects of insulation mean low (FEB) to mean high (JULY) is likely seasonal swing.
i.e. 11.2 – (-29.2) = 40.4 °C OR 73 °F

For 316 Stainless Expansion Coeff = 0.000017 cm/cm °C

For L = 1, 100

Expansion = 1,100 x 100 x 0.000017 x 73
= 137 cm

2) Due to Heat Trace Continuous Operation

For 22 W/m input

May $T_W - T_A$ = 116 °C

If T_A = 0 -°C – i.e. early or late summer

$T_{internal}$ = 116 °C if empty

With flowing water internal temp goes to water temp.i.e. 5 °C
$\triangle$T = 111 °C

Expansion = 1100 x 100 x 0.000017 x 111
= 208 cm

If Ta = -40°C

$T_{Internal}$ = 76°C – Pipe empty
T_{In} = 0°C - Pipe full
Δ T = 76°C
Expansion = 1100 x 100 x .000017x76 = 142 cm

Summary
For 1100 m length
Seasonal variation ~ 140 cm
Operating variation is between 140 and 210 cm

E) Summary

1. Temperature Depression

   During winter
   With heaters on, arriving temperature at truck fill ≈ 3°C

   During winter with - 30°C
   Ambient and heater off water arrives near freezing

2. Heat Loss

   For temperature difference between water and ambient less than 50°C
   Heat loss ≤ 10 w/m

   Heat trace installed capacity = 22 w/m

3. Highest potential temperature is 116°C above ambient

4. Thermal Expansion

   For 1,100 m
   Seasonal variation ≈ 140 cm
   Operational variation during fill cycle between 140 and 210 cm

5. Installed heat trace capability

   = 22 w/m
   Next size thermon cable provides
   11.2 w/m
   Stipulated requirement = 11.8 w/m

Appendix B

References

A) Canadian Climate Normals
B) Steady State Thermal Equations for above Surface Pipes
C) Temperature Drop and Freeze-up Time in Pipes

Environment Canada Environnement Canada

Canadian Climate Normals 1971-2000

The minimum number of years used to calculate these Normals is indicated by a code for each element. A "+" beside an extreme date indicates that this date is the first occurrence of the extreme value. Values and dates in bold indicate all-time extremes for the location.

NOTE!! Data used in the calculation of these Normals may be subject to further quality assurance checks. This may result in minor changes to some values presented here.

CAPE DORSET A
NUNAVUT

Latitude: 64° 13' N **Longitude:** 76° 31' W **Elevation:** 50.00 m
Climate ID: 2400635 **WMO ID:** 71910 **TC ID:** YTE

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Code
Daily Average (°C)	-25.0	-26.0	-21.6	-14.1	-5.5	2.3	7.4	5.7	1.5	-3.9	-11.7	-20.2	-9.3	D
Standard Deviation	3.3	2.8	2.8	2.0	1.8	1.4	1.2	1.3	1.2	1.5	2.7	4.0	5.4	D
Daily Maximum (°C)	-21.7	-22.7	-17.9	-10.3	-2.7	5.1	11.2	8.8	3.6	-1.8	-8.7	-16.9	-6.2	D
Daily Minimum (°C)	-28.3	-29.2	-25.1	-18.0	-8.3	-0.6	3.5	2.5	-0.7	-5.9	-14.8	-23.4	-12.4	D
Extreme Maximum (°C)	-1.4	-1.5	0.8	5.6	10.9	17.9	**25.0**	21.9	18.1	7.2	3.4	-0.8		
Date (yyyy/dd)	1985/18	1986/27	1999/28	1975/29+	1993/31	1985/15	**1984/15**	1991/09	1989/10	1998/02	1985/02	1998/05+		
Extreme Minimum (°C)	-38.9	-40.6	-42.2	-32.8	-19.6	-9.3	-3.4	-4.6	-8.3	-23.9	-30.6	**-42.8**		
Date (yyyy/dd)	1964/14	1964/26	1964/11	1963/01	1983/15	2000/04	1983/11	1983/23	1963/30+	1986/25	1963/28	**1971/30**		
Precipitation:														
Rainfall (mm)	0.0	0.0	0.0	0.1	3.1	14.7	34.4	54.7	32.5	4.3	0.0	0.0	143.9	D
Snowfall (cm)	25.5	20.4	25.7	34.6	30.7	9.3	0.4	1.4	14.1	42.8	50.2	41.5	296.4	D
Precipitation (mm)	22.3	17.3	21.8	30.1	31.1	23.7	34.4	56.0	46.7	44.3	42.4	33.1	403.0	D
Average Snow Depth (cm)	48	46	52	59	56	19	0	0	0	6	22	36	29	D
Median Snow Depth (cm)	49	46	52	57	57	18	0	0	0	6	21	36	29	D
Snow Depth at Month-end (cm)	48	47	55	58	41	1	0	0	1	13	28	40	28	D
Extreme Daily Rainfall (mm)	0.0	0.0	0.0	1.2	11.4	35.2	24.8	**41.2**	32.0	17.3	0.6	0.2		
Date (yyyy/dd)	1964/01+	1963/01+	1963/01+	2001/30	1980/30	2001/17	1995/02	**1986/20**	1998/10	1973/11	1985/02	1998/04		
Extreme Daily Snowfall (cm)	29.7	20.3	13.6	23.0	19.0	15.6	2.6	9.2	19.6	20.2	25.7	15.7		

Extreme Daily Precipitation (mm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Date (yyyy/dd)	1971/28	1964/02	1990/09	1995/09	1991/23	2001/17	1995/02	**1986/20**	1998/10	1999/31	1970/23	1971/05		
Extreme Snow Depth (cm)	127.0	84.0	88.0	**147.0**	94.0	90.0	3.0	0.0	18.0	36.0	74.0	92.0		
Date (yyyy/dd)	1975/13+	2001/26+	2001/26+	**1975/02+**	1983/24	1987/03	1992/01	1971/01+	1992/24	1974/29+	1989/28+	1993/20+		
Days with Maximum Temperature:														
<= 0 °C	31.0	28.3	30.8	29.2	23.8	2.4	0.0	0.0	3.8	23.0	29.1	31.0	232.3	D
> 0 °C	0.0	0.0	0.24	0.77	7.2	27.6	31.0	31.0	26.2	8.1	0.94	0.0	133.0	D
> 10 °C	0.0	0.0	0.0	0.0	0.06	4.2	18.1	10.4	1.0	0.0	0.0	0.0	33.7	D
> 20 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.41	0.09	0.0	0.0	0.0	0.0	0.50	D
> 30 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	D
> 35 °C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	D
Days with Minimum Temperature:														
> 0 °C	0.0	0.0	0.0	0.0	0.23	10.2	27.9	26.4	11.1	0.42	0.0	0.0	76.3	C
<= 2 °C	29.8	27.3	30.0	28.5	29.1	24.7	9.7	13.3	25.1	29.3	28.6	28.7	304.2	C
<= 0 °C	29.8	27.3	30.0	28.5	28.9	18.5	1.3	3.0	17.2	28.9	28.6	28.7	270.8	C
< -2 °C	29.8	27.3	29.9	28.3	26.8	7.2	0.10	0.16	7.5	25.7	28.4	28.7	239.9	C
< -10 °C	29.8	27.3	29.3	24.6	9.6	0.0	0.0	0.0	0.0	3.5	21.2	27.6	173.0	C
< -20 °C	27.1	25.7	24.1	10.6	0.0	0.0	0.0	0.0	0.0	0.08	5.4	20.1	113.0	C
< - 30 °C	12.2	13.1	5.8	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	36.3	C
Days with Rainfall:														
>= 0.2 mm	0.0	0.0	0.0	0.25	1.8	6.1	11.6	12.6	10.1	2.2	0.05	0.05	44.7	C

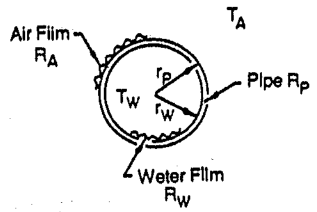
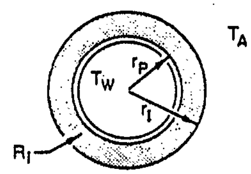
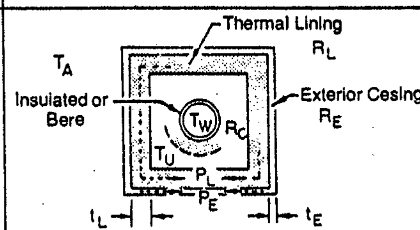
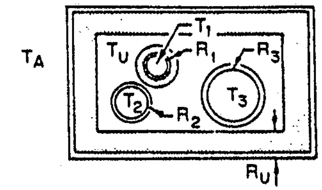
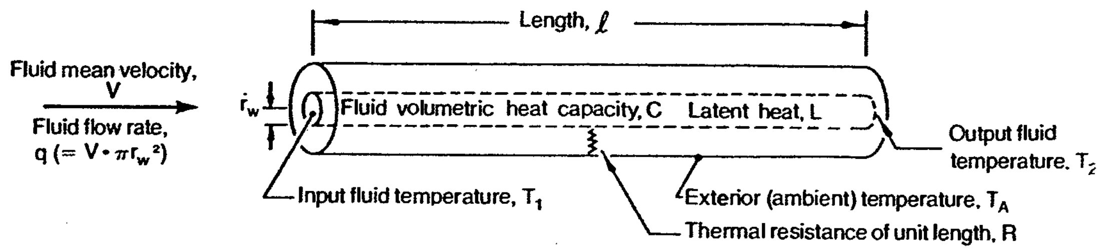
	(a) Bare Pipe	(b) Insulated Pipe	(c) Single Pipe in a Box	(d) Multiple Pipe Utilidor
Sketch				
Assumptions	Thin walled pipe (i.e. $r_P \approx 2 r_W$). R_W is negligible. $R_P \approx R_A$.	All thermal resistances but that of the insulation are neglected.	Convection ensures the temperature inside the utilidor, T_U, is uniform. Utilidor air films neglected.	Same as (c).
Thermal Resistance	$R_P = (r_P - r_W)/(r_P + r_W)\ \pi\ k_P$ $h_A = N \left(\frac{T_W - T_A}{r_P}\right)^{0.25} W$ $R_A = 1/2\pi r_P h_A$ $R_C = R_P + R_A$ $N = 0.23\ Btu/h \cdot ft^{\frac{7}{4}} \cdot °F^{\frac{5}{4}}$ $W = \sqrt{12.5 V + 1}$ for V = miles/h $N = 1.12\ J/s \cdot m^{\frac{7}{4}} \cdot °C^{\frac{5}{4}}$ $W = \sqrt{0.56 V + 1}$ for V = m/s	$R_C = R_I = \frac{\ln(r_I/r_P)}{2\pi k_I}$ $\approx \left(\frac{r_I - r_P}{r_I + r_P}\right) / \pi k_I$ if $r_I \approx 2 r_P$ Or given r_I/r_P and k_I; read off R_I from graph	Calculate R_C, the thermal resistance of the interior conduit by: using (b) if insulated or using (a) if bare and replacing T_A in the formula for h_A by an estimate for T_U ($\leq T_W$) $R_L = t_L / P_L k_L$ $R_E = t_E / P_E k_E$ $R_U = R_L + R_E$ $R = R_C + R_U$ $T_U = \frac{(T_W/R_C) + (T_A/R_U)}{(1/R_C) + (1/R_U)}$ If bare pipe, iterate T_U	Calculate R for each pipe as in (c) to get R_J, (J = 1, 2, 3, . . .). Calculate R_U as in (c) $T_U = \frac{\sum_J (T_J/R_J) + (T_A/R_U)}{\sum_J (1/R_J) + (1/R_U)}$ If bare pipes present, iterate T_U
Rate of Heat Loss	$Q = (T_W - T_A)/R_C$	$Q = (T_W - T_A)/R_I$	$Q = (T_W - T_A)/R$	$Q_J = (T_J - T_U)/R_J$ (per pipe) $Q = \sum_J Q_J = (T_U - T_A)/R_U$
Insulation Thickness (given Q)	N/A	$r_I - r_P = r_P\{\exp[2\pi k_I (T_W - T_A)/Q] - 1\}$ $\approx \pi k_I (T_W - T_A) Q$ if $r_I \approx 2 r_P$ Or given R_I and k_I; read off r_I/r_P from graph	Obtain R_E and R_C as above $t_U = P_L k_L \left[\frac{(T_W - T_A)}{Q} - R_E - R_C\right]$ If bare interior pipe, iterate T_U, R_C and hence t_L	Given acceptable Q_J, calculate R_J as above and evaluate $T_U = T_J - R_J Q_J$ **for each pipe for which Q_J is known.** Using the **maximum** T_U found, calculate new Q_J as above. Using these Q_J and the same T_U, evaluate $t_L = R_L k_L \left[\frac{T_U - T_A}{\sum Q_J} - R_E\right]$ If bare pipes present, iterate T_U, R_J and hence t_L
Comments	Often, for metal pipes, R_P may be neglected. If R_P is significant, the expression above for h_A will generate an overestimate of Q. If $T_A > T_W$ switch T_A and T_W in the expression for h_A.	The neglected thermal resistances given in (a) may be included if desired. Estimate a value for the insulation surface temperature and calculate h_A and R_A. Interate.	The value of h_A, and hence R_A, is fairly insensitive to the choice of T_U, and so one iteration on T_U is usually sufficient. Often R_E may be neglected. Similar calculational procedure may be performed for pipes and utilidors of different cross-section.	as (c). If it is clear that one pipe dominates the heat loss process, (c) may be used to estimate T_U. It is wise to consider the heat loss from the various pipes if certain other pipes cease to function.

FIGURE 15-10. STEADY-STATE THERMAL EQUATIONS FOR ABOVE-SURFACE PIPES [adapted from 82]

Heat Loss and Temperature Drop in a Fluid Flowing Through a Pipe

Freeze-Up Time For a Full Pipe Under No-Flow Conditions (V = 0)



Comments: The above sketch is schematic. R and T_A appearing in these equations can be replaced by the thermal resistance and corresponding exterior temperature for any shape or configuration.

$D = \pi r_w^2 \, V \cdot C \cdot R$

Calculate T_1 or T_2, Given R, T_1 or T_2, T_A

$T_1 = T_A + (T_2 - T_A) / \exp(-\ell/D)$

$\approx T_A + (T_2 - T_A)/(1 + \ell/D)$ if $\ell/D \lesssim 0.1$

$T_2 = T_A + (T_1 - T_A)\exp(-\ell/D)$

Calculate R, Given T_1, T_2, T_A

$R = \ell / \pi r_w^2 \cdot V \cdot C \cdot \ln[(T_2 - T_A)/(T_1 - T_A)]$

$\approx \ell (T_1 - T_A) / \pi r_w^2 \cdot V \cdot C \, (T_1 - T_2)$ if $\ell/D \lesssim 0.1$

Calculate V, Given T_1, T_2, T_A, R

$V = \ell / \pi r_w^2 \cdot R \cdot C \cdot \ln[(T_2 - T_1)/(T_1 - T_A)]$

$\approx \ell (T_1 - T_A) / \pi r_w^2 \cdot V \cdot C (T_1 - T_2)$ if $\ell/D \lesssim 0.1$

Calculate Heat Loss (Q), Given T_1 or T_2, T_A, V, R

$Q = (D/R)(T_1 - T_A)[1 - \exp(-\ell/D)]$

$\approx (\ell/R)(T_1 - T_A)$ for $\ell/D \lesssim 0.1$

$= D/R \, (T_2 - T_A)\left[\exp(\ell/D) - 1\right]$

Calculate Friction Heating, Given V, f

$Q_f = F \cdot r_w^2 \cdot V \cdot f$

Where: Q_f = BTU / h • ft
F = 0.2515 BTU / ft⁴
r = ft
V = ft / h
f = friction head loss, ft / ft length
Not significant for $V \lesssim 2.3 \times 10^4$ ft / h

or Q_f = J / s • m
$F = 3.074 \times 10^4$ J / m⁴
r = m
V = m / s
f = friction head loss, m / m length
Not significant for $V \lesssim 2$ m · s

Freeze-Up Times; Given R, T_1, T_A

Assume that thermal resistance of the ice, as it forms, and the heat capacity of the pipe and insulation are negligible.

Design Time (Recommended)

t_D = Time for the fluid temperature to drop to the freezing point.

$= \pi \cdot r_w^2 \cdot R \cdot C \cdot \ln[(T_1 - T_A)/(T_O - T_A)]$

$= \pi \cdot r_w^2 \cdot R \cdot C \, [(T_1 - T_O)/(T_1 - T_A)]$

for $[(T_1 - T_O)/(T_1 - T_A)] \leq 0.1$

or $T_1 \lesssim 0.11 \, T_A$ (in °C)

Safety Factor Time

t_{SF} = Time for the fluid to drop to the nucleation temperature. Same as t_D but with T_O replaced by −3°C.

Complete Freezing Time

t_F = Time for the fluid at freezing point, 0°C, to completely freeze solid.

$= \pi \cdot r_w^2 \cdot R \cdot L / (T_O - T_A)$

Calculate R, Given a No-Flow Time

Design Choice

R_D = time / $\pi \cdot r_w^2 \cdot C \cdot \ln[(T_1 - T_A)/(T_O - T_A)]$

Minimum Resistance

R_{SF} = same as R_D but with T_O replaced by −3°C.

FIGURE 15-13. TEMPERATURE DROP AND FREEZE-UP TIME IN PIPES [adapted from 82]

Appendix C
Heating Cable

A) Verification of Selected Cable

B) Mineral Insulated Cable - Product Specification

Selected Cable

For MQ – 10E14 – 2S
1 Ω/ft
70 m →230 ft→230 Ω

At 600 V; I = 600/230 = 2.6 A
P=IV= 600 x 2.6
= 1565 w or $\frac{V^2}{R} = \frac{600^2}{230}$
Or 22 w/m

Other Cables

MIQ – 70 E2H – 2S
-0.7 Ω/ft
For 70 m→ 161 Ω
P= $\frac{Y^2}{R} = \frac{600^2}{161}$ =2,236 or
32 w/m
For M1Q – 20 E1H – 2S
2.0 Ω/ft
70 m → 230 ft →460Ω
600 Volts

P= $\frac{V^2}{R} = \frac{600^2}{460}$ =11.2 w/m

Requested cable capacity = 11.8 w/m

MIQ™
Mineral Insulated Cable

Product Specifications

Application . . .

Process Temperature Maintenance or Freeze Protection
MIQ high performance mineral insulated heating cables are used extensively for high temperature maintenance, high temperature exposure and/or high watt density applications which exceed the limitations of thermoplastic insulated cables. The resistance configurations available can provide tracing for pipes up to 1 mile (1.6 km) long from a single power supply point.

Thermon's MIQ mineral insulated cables are manufactured using Alloy 825, a high nickel/chromium alloy ideally suited for high temperature service that offers exceptional resistance to stress corrosion in chloride, acid, salt and alkaline environments.

MIQ cables are approved for use in ordinary (nonclassified) areas, hazardous (classified) areas, and Zone 1 and 2 classified areas.

Ratings . . .

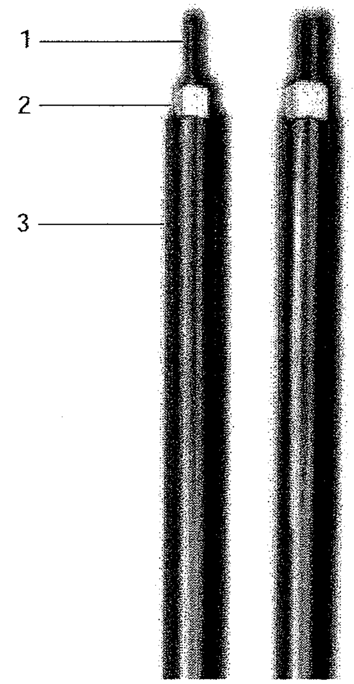
Rated voltage[1] .... 300 and 600 Vac
Max. maintenance temperature[2] .... 932°F (500°C)
Max. continuous exposure temperature
  Power-off .... 1,100°F (593°C)
Max. watt density[2] .... up to 80 w/ft (262 w/m)
Minimum bend radius .... 6 x cable O.D.

MIQ Heater Sets . . .

Thermon MIQ cable sets are available in four factory fabricated configurations: Type A, B, D or E. The standard assemblies consist of a predetermined length of heating cable joined to a standard[3] 4' (1,220 mm) nonheating cold lead with 8" (203 mm) long thermoplastic insulated pigtails.

The nonheating section of the unit is sealed and fitted with a high pressure, liquid-tight 1/2" or 3/4" NPT stainless steel gland[4] for connection into the supply junction box.

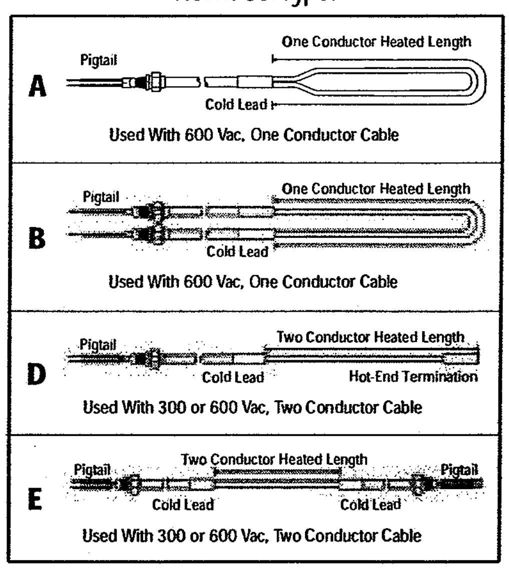
Notes . . .
1. Definition as stated in IEEE Standard 515-1997. Specific voltage depends on circuit length and design conditions.
2. Watt density limitations are correlated to maintain temperatures. Maximum watt density for CSA certified application is 50 w/ft (164 w/m).
3. Cold lead will be sized for the circuit operating current in accordance with relevant NEC or CEC code requirements.
4. Cold lead gland is ½" NPT except for 2-conductor sets with larger wire sizes for which a ¾" NPT gland is provided.



Construction . . .

1 Solid Alloy or Copper Conductor(s)
2 Compacted Magnesium Oxide Insulation
3 Seamless Alloy 825 Sheath

Heater Set Types



THERMON . . . The Heat Tracing Specialists®

100 Thermon Dr. • PO Box 609 • San Marcos, TX 78667-0609
Phone: 512-396-5801 • Facsimile: 512-396-3627 • **800-820-HEAT**
www.thermon.com In Canada call **800-563-8461**

MIQ™
Mineral Insulated Cable

INSTALLED CABLE -70M LONG. SEE REVERSE

Product Specifications

Available MIQ Cables[1] . . .

600 Vac Cable—Two Conductor—Heater Set Type D or E

Catalog Number	Resistance[2] ohms/ft	Resistance[2] ohms/m	Nominal Diameter in	Nominal Diameter mm
MIQ-11EOH-2S	11.0	36.1	0.215	5.46
MIQ-90E1H-2S	9.0	29.5	0.230	5.84
MIQ-60E1H-2S	6.0	19.7	0.230	5.84
MIQ-40E1H-2S	4.0	13.1	0.235	5.97
MIQ-20E1H-2S	2.0	6.56	0.270	6.86
MIQ-10E1H-2S	1.0	3.28	0.255	6.48
MIQ-70E2H-2S	0.70	2.30	0.265	6.73
MIQ-50E2H-2S	0.50	1.64	0.280	7.11
MIQ-30E2H-2S	0.30	0.98	0.307	7.80
MIQ-20E2H-2S	0.20	0.66	0.255	6.48
MIQ-15E2H-2S	0.15	0.49	0.265	6.73
MIQ-10E2H-2S	0.10	0.33	0.280	7.11
MIQ-70E3H-2S	0.070	0.23	0.295	7.49
MIQ-50E3H-2S	0.050	0.16	0.312	7.92
MIQ-40E3H-2S	0.040	0.13	0.325	8.26
MIQ-30E3H-2S	0.030	0.098	0.350	8.89
MIQ-20E3H-2S	0.020	0.066	0.275	6.99
MIQ-16E3H-2S	0.016	0.052	0.285	7.24
MIQ-13E3H-2S	0.013	0.043	0.295	7.49
MIQ-10E3H-2S	0.0104	0.0341	0.307	7.80

INSTALLED

600 Vac Cable—One Conductor—Heater Set Type A or B

Catalog Number	Resistance[2] ohms/ft	Resistance[2] ohms/m	Nominal Diameter in	Nominal Diameter mm
MIQ-20E1H-1S	2.0	6.56	0.170	4.32
MIQ-16E1H-1S	1.6	5.25	0.170	4.32
MIQ-13E1H-1S	1.3	4.26	0.170	4.32
MIQ-10E1H-1S	1.0	3.28	0.170	4.32
MIQ-85E2H-1S	0.85	2.79	0.170	4.32
MIQ-70E2H-1S	0.70	2.30	0.170	4.32
MIQ-50E2H-1S	0.50	1.64	0.170	4.32
MIQ-38E2H-1S	0.38	1.25	0.170	4.32
MIQ-30E2H-1S	0.30	0.98	0.170	4.32
MIQ-25E2H-1S	0.25	0.82	0.170	4.32
MIQ-20E2H-1S	0.20	0.66	0.175	4.45
MIQ-17E2H-1S	0.17	0.56	0.180	4.57
MIQ-15E2H-1S	0.15	0.49	0.170	4.32
MIQ-10E2H-1S	0.10	0.33	0.170	4.32
MIQ-80E3H-1S	0.080	0.26	0.170	4.32
MIQ-70E3H-1S	0.070	0.23	0.170	4.32
MIQ-60E3H-1S	0.060	0.20	0.170	4.32
MIQ-40E3H-1S	0.040	0.13	0.180	4.57
MIQ-30E3H-1S	0.030	0.098	0.185	4.70
MIQ-20E3H-1S	0.020	0.066	0.200	5.08
MIQ-10E3H-1S	0.010	0.03395	0.170	4.32
MIQ-65E4H-1S	0.00651	0.02135	0.180	4.57
MIQ-40E4H-1S	0.00409	0.01342	0.195	4.95
MIQ-25E4H-1S	0.00258	0.00846	0.210	5.33
MIQ-16E4H-1S	0.00162	0.00531	0.240	6.10

300 Vac Cable—Two Conductor—Heater Set Type D or E

Catalog Number	Resistance[2] ohms/ft	Resistance[2] ohms/m	Nominal Diameter in	Nominal Diameter mm
MIQ-11E0L-2S	11.0	36.1	0.160	4.06
MIQ-90E1L-2S	9.0	29.5	0.160	4.06
MIQ-75E1L-2S	7.5	24.6	0.160	4.06
MIQ-60E1L-2S	6.0	19.7	0.160	4.06
MIQ-50E1L-2S	5.0	16.4	0.160	4.06
MIQ-40E1L-2S	4.0	13.1	0.160	4.06
MIQ-32E1L-2S	3.20	10.5	0.160	4.06
MIQ-27E1L-2S	2.75	9.02	0.160	4.06
MIQ-25E1L-2S	2.50	8.20	0.160	4.06
MIQ-20E1L-2S	2.00	6.56	0.160	4.06
MIQ-17E1L-2S	1.70	5.58	0.160	4.06
MIQ-14E1L-2S	1.40	4.59	0.160	4.06
MIQ-10E1L-2S	1.00	3.28	0.170	4.32
MIQ-70E2L-2S	0.70	2.30	0.180	4.57
MIQ-50E2L-2S	0.50	1.64	0.195	4.95
MIQ-30E2L-2S	0.30	0.98	0.170	4.32
MIQ-25E2L-2S	0.25	0.82	0.170	4.32
MIQ-20E2L-2S	0.20	0.66	0.170	4.32
MIQ-15E2L-2S	0.15	0.49	0.175	4.45
MIQ-10E2L-2S	0.10	0.33	0.195	4.95
MIQ-70E3L-2S	0.070	0.23	0.210	5.33
MIQ-50E3L-2S	0.050	0.16	0.230	5.84

Circuit Breaker Sizing and Type . . .

Breaker sizing should be based on the National Electrical Code, Canadian Electrical Code or any other applicable code.

The National Electrical Code and Canadian Electrical Code require ground-fault protection of equipment for each branch circuit supplying electric heating equipment. Check local codes for ground-fault protection requirements.

Certifications/Approvals . . .

Factory Mutual Research
Ordinary Locations
Hazardous (Classified) Locations
- Class I, Division 1 Groups B, C and D
- Class I, Division 2, Groups A, B, C and D
- Class II, Divisions 1 and 2 Groups E, F and G
- Class III, Divisions 1 and 2
- Class I, Zone 1, Group IIB + H_2
- Class I, Zone 2, Group IIC

Canadian Standards Association
Ordinary Locations
Hazardous (Classified) Locations
- Class I, Division 1 Groups B, C and D
- Class I, Division 2, Groups A, B, C and D
- Class II, Divisions 1 and 2, Groups E, F and G
- Class I, Zone 1, Group IIB + H_2
- Class I, Zone 2, Group IIC

Notes . . .

1. Other resistances are available. Contact Thermon for design assistance.
2. All resistances shown are per length of cable at 68°F (20°C) and are subject to a ±10% manufacturing tolerance.

Thermal Computations
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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April 2005

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Introduction

Trow Associates Inc. undertook a detailed review of the thermal issues relating to the Cape Dorset water supply main. Issues included in the review included:

1. Estimate the heat loss under extreme conditions.
2. Determine the sensitivity to variability and deterioration of insulation.
3. Compare calculated heat loss with the selected heating cable system
4. Estimate the amount of thermal expansion.

Thermal calculations for the water supply pipeline have been prepared and are attached.

Summary of Findings

The following are the principle findings of the thermal calculations (included in Appendix A):

- During winter conditions (-30°C ambient) water should arrive at the Truck Fill Station at approximately 3°C if the immersion heaters are in operation. The arriving temperature is close to the freezing point if the heaters are not in operation.
- For a temperature difference across the insulation system of 50°C, heat loss is less that 10W/m. The installed heat trace capacity is 22W/m.
- Continuous operation of the present heat trace cable could raise the temperature 116°C above ambient if sufficient time past to establish steady state conditions.
- Thermal expansion along the 1,100 metre stainless steel pipeline is between 140 centimetres and 210 centimetre due to seasonal and operating variations in temperature.

Appendix A:
Thermal Computations

A) System Description
B) Temperature Depression
C) Heat Loss Rate
D) Thermal Expansion
E) Summary

Appendix B
References

A) Canadian Climate Normals
B) Steady State Thermal Equations for above Surface Pipes
C) Temperature Drop and Freeze-up Time in Pipes

Appendix C
Heating Cable

A) Verification of Selected Cable

B) Mineral Insulated Cable - Product Specification

Heat Trace System Operation Intent
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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Understanding of Trow

It is Trow Associates Inc. (Trow) understanding that the existing Truck Fill Station was designed with the same operational philosophy for the heat trace system as the original Truck Fill Station, however the process was automated. The heat trace cable was operated for a period of one to two hours prior to pumping water to pre-heat the piping from the Heater House to the Truck Fill Station. Following the tank fill cycle the heat trace cable was again energized for another one to two hours to dry the pipeline. Due to the success of this mode of operation it was incorporated into the design of the controls of the new Truck Fill Station.

Recent System Improvements

Both the Planning Study (Reid Crowther Partner Limited 1997) and the Concept Brief (Dillon Consulting Limited 2000) provide some information regarding the current operating mode for the water supply pipeline heat trace system.

Reid Crowther Partner Limited

Reid Crowther Partner Limited (RCPL) reported the tank refill sequence included the following:

- Heat trace is energized when air temperature is less than 5°C for as long as is required to raise the pipeline to 5°C.
- The pipeline is drained following tank refill.
- The heat trace operates for a further 2 hours following draining of the pipeline.

This reports recommends among other matters the following:

- Modifications to the control system to cause a pipeline drain cycle following a power failure.
- Evaluation of those circumstances when the immersion heaters are required with the intention of reducing frequency of use and thus operating cost.

The RCPL report does not recommend modifications to the operating mode for the pipeline heat trace system.

Dillon Consulting Limited

The Dillon Consulting Limited (Dillon) Concept Brief reports largely the same information as is set out above regarding operation of the heat trace with the following minor exceptions.

- Heat trace is operated for approximately 1 hour prior to pumping water to preheat the pipeline.

- Heat trace is operated for approximately 1 hour at the end of the tank fill cycle pipeline draining.

The Concept Brief examines the heat trace system and does not recommend modifications to the operating mode. Recommendations are presented for various modifications to the heat trace system including limiting heat trace cable lengths to 70 metres and provision of an ambient air temperature sensor to avoid operation during the summer.

The Concept Brief does not recommend continuous operation of the heat trace system during the winter.

Contract Change Order No. 3

A letter of August 10, 2002 requested, as an optional item of work, a quotation for continuous operation of the heat trace during winter including thermostatic control. Pricing for this item is provided in a Nunavut Construction Limited (NCL) letter of August 30, 2002. The total value of the work quoted was $36,551.73. Based on the wording and value of Change Order No. 3 of $36,551.23 it is assumed that direction was provided to the contractor to perform this control modification. No information in support of this change beyond the information cited above was available for our review.

Heat Trace Related Issues

Comment has been sought for various issues related to the heat tracing system for the water supply pipeline. These have included the electrical metering of the heat trace system and the current operating mode of this system.

Electrical Metering

Currently there is an analogue ammeter in the Truck Fill Station indicating total current drawn by the heat trace system. This meter indicates, in a general sense, that the heat trace system is in operation but provides little additional information. Prior to the most recent modifications, single runs of heat trace cable served the upper and lower halves of the pipeline. Failure of the either heating cable would lead to a large and observable change in the indicated current. In this circumstance the present metering provided the required operation information.

This system was replaced with several heating cables, each protecting a 70 metre section of pipeline. Each segment of heating cable is rated at 2.6 amperes. The failure of any single section of heat trace cable is not identifiable as the change is electrical load is not practically detectable with the current instrument. It has been suggested that a digital ammeter be considered as a replacement. This equipment will likely have the resolution required to detect the failure of a single heat trace cable, but the determination of such a fault would require daily logging of heat trace electrical load to detect changes. This system will not provide indications of the location of heat trace faults. Thus the response to a change in heat trace current would entail verification of the entire system to locate the faulted heat trace cable. As a monitoring system, a digital ammeter represents a lower cost but incomplete solution.

An alternative scheme is based upon current detection for each heat trace cable or each powered junction box, and a central status indicator in the Truck Fill Station. This system carries the desirable feature of clearly identifying faulted cables or pairs of cables and the location of such faults. Such a system would represent a significantly more costly solution due to the need for load detection at each powered junction box together with cabling along the length of the pipeline. This system would be substantially more convenient from an operational point of view, especially in determining the location of faults during winter.

Additional information can be developed for the heat trace monitoring system following the selection of a preferred system.

Heat Trace Operating Mode

Direction to alter the heat trace control to provide continuous operation during winter was included in Changer Order No. 3, approved by the Department in September 2002. Documentation in support of this change has not been provided for review. It is presumed that this modification was carried out for sound reasons. High energy costs in Cape Dorset together with the previous successful history with heat trace forming part of the tank refill cycle suggests that further review is in order. Background data, including the following measurements, is necessary for this review.

- Data to determine the thermal balance of the system and the rates of heat loss including water temperatures at the lake, at the input and discharge sides of the Heater Building and at the input to the Truck Fill Storage.
- Confirmation of the electrical consumption of the immersion heaters.
- Confirmation of the flow rate through measurement of tank refill rate.

Summary

The documentation related to Change Order No. 3 indicates the contractor has been directed to change the operating mode of the heat trace system to provide continuous operation during the winter season. Documents that explain this change in operational mode were not provided, therefore comments on this decision cannot be expressed.

The Operational and Maintenance Manual for the Truck Fill Station should reflect the current operational philosophy for the heat trace system.

2004 Pipeline Stabilization Program
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

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April 2005

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Appendices

Appendix A:

SK1: Clamping Sleeve Installation
SK2: Clamping Sleeve
SK3 Lug Detail for Clamping Sleeve
SK 4 2004 Program As-built

Appendix B:

Memo to File: Phone conversation with General Contractor of 2004 Works

Proposed Remedial Measures - Fall of 2004

The proposed 2004 remediation was based on a clamp-on sleeve system, which is to be secured around the exterior of the insulated pipe and attached by cables to the existing pipe support system. These sleeves were to be installed in two locations, specifically, immediately below the heater building and immediately below the expansion loop. It was proposed that four (4) of these sleeves be used at each location. The attached details SK-1, SK-2 and SK-3 show the proposed measures to restrain the water pipeline over the winter of 2004-2005.

It was our further suggestion that the restraint of the pipeline at the existing road crossing be removed to reduce the risk to the pipeline from expansion below the existing expansion loop. Additionally, a procedure for the installation of these clamps, the pulling of the pipeline into its original location and the securing of the clamping system was presented.

Procedure for 2004 Remedial Measures

The pipeline downhill of the expansion loop was to be jacked first. Eight stainless steel sleeves were to be installed approximately 5 metres apart at this location. Once the jacking procedure was completed in this area the four lower sleeves were to be removed and installed to the north of the Heater House.

The pipeline downhill of the Heater House was to be jacked second. Four stainless steel sleeves were to be installed 5 metres apart at this location.

The following procedure of sleeve installation and jacking was to be followed:

1. Existing temporary remedial measures at expansion loop and junction box to be left in place.
2. Prior to installing new stainless steel sleeve ensure existing insulation jacket is clean and dry.
3. Install new neoprene sleeve ensuring that the neoprene is clean, with no factory oils or coating
4. Install new clamping sleeve centred between two adjacent piles. Bolts for clamping sleeve are to be 20 millimetre diameter A325 bolts galvanized. Bolts were to be brought to a snug-tight condition to ensure that the parts of the joint are brought into full contact. Following the initial snugging operation each bolt in the joint shall then be tightened additionally ¾ of a turn from the most rigid part of the joint to its free edges.
5. A steel plate lug was to be welded to the adjacent pile at the sleeve location to allow installation of a cable between the sleeve and pile. The steel lug is to be located as close to the base of the pile as possible; a maximum distance of 75 millimetre from existing grade.
6. With the stainless steel sleeve and pile lug in place the ¾ inch diameter steel cable was to be connected between the sleeve lug and pile lug. The angle of the cable with respect to the pipeline was not to be greater than 35 degrees. Contractor to confirm to Engineer configuration of cable and accessories utilized. Provide shop drawings for approval.

7. Tighten cables using the turnbuckles.

8. Remove fixity at roadway crossing. During removal, carefully observe any movements of the pipeline

9. Remove lateral clamps below expansion loop prior to jacking pipeline

10. Starting with the lowest cable and proceeding to the top most cable tighten the cables sequentially to pull pipeline at most ½ inch. Repeat the process as required to reposition pipeline. **During jacking process, visually examine the pipeline along its full length for signs of distress or excessive lateral movement after each pull**.

11. Reinstate lateral clamps on pipeline below expansion loop.

Summary of 2004 Works Completed by Contractor

The following is a summary of the temporary remedial works on the Cape Dorset Pipeline constructed during 2004. An initial summary of the specified remedial measures was provided to the Government of Nunavut and the Contractor on September 3rd, 2004. A summary of the actual works performed, as reported by the Contractor to our office on October 19th, 2004 is included in Appendix A.

The temporary measures for 2004 specified a total of eight (8) clamped sleeves installed in two areas; specifically these were to be installed immediately below the Heater House and immediately below the expansion loop. Four (4) sleeves were to be installed at each location at 5 metre intervals.

The Contractor provided information as to the work performed. The pipeline was winched up by approximately 7½ inches as measured at the expansion loop. The lower leg of the expansion loop is reported as being square. The pipeline is no longer touching the edges of the culvert at the road crossing but is centred within it.

A total of twelve (12) restraints were added to the pipeline. The following is a summary of the locations of the installed sleeves. Refer to SK4 for approximate locations.

1. One clamped sleeve installed below the pump heater house. Four sleeves at 5 metre intervals were requested in this area. Weather conditions did not permit the use of any motor vehicle. The contractor attempted to use one of the existing rock anchors to hold the sleeve. We had specified the use of lugs on the supports. Since the rock anchors failed, he did fix the lug onto the support as specified.

2. A total of eleven restraints were installed between the Truck Fill Station and the Expansion Loop.

    - One (1) restraint was installed immediately below the roadway crossing. None were specified in this area.

- Three (3) restraints were installed immediately above the roadway crossing at intervals of approximately 30 metres along the flatter terrain. These were placed in the vicinity of junction boxes, at approximately 70 metre intervals.
- The remaining seven (7) were installed at approximately 35 metre intervals below the expansion loop. One of the restraints was fixed at the lower leg of the expansion loop. Four sleeves were requested immediately downhill of the expansion loop at 5 metre intervals.

Concerns Arising from 2004 Program

The work performed is not consistent with the Remedial Measure Procedures provided to the Government of Nunavut and the Contractor on September 3rd, 2004. The principle concerns arising from the 2004 works are as follows:

1. There is currently insufficient restraint at the Heater House increasing the risk of movement at the Heater House connection. It is anticipated that the installation of the 2005 remediation program will reduce the risk of movement at the Heater House. Four welded stainless steel assemblies secured to rock anchors are specified in the 2005 program.

2. The Contractor indicated that he did not purchase rock anchors as specified on the September 8th Materials list for the 2005 stabilization of the pipeline. The current pipeline support piles in this location will not provide adequate lateral resistance. Furthermore, adfreeze piles in this location are not viable.

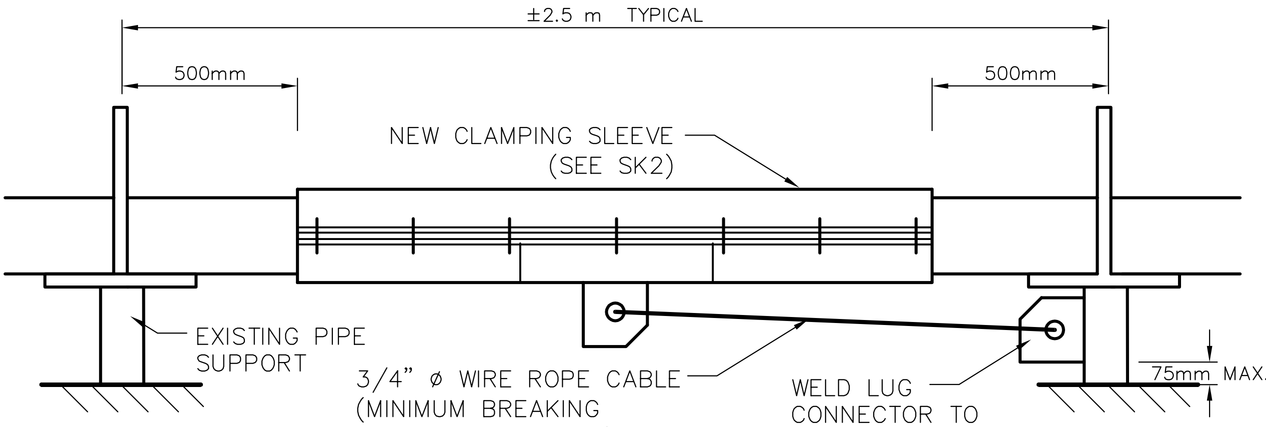
3. Shop drawings of hardware purchased and installed by the Contractor were not provided. Shop drawings should be provided prior to any further work for the 2005 program.

4. The fixity below the roadway crossing is a concern. The Contractor installed one clamped sleeve below the road crossing and the crossing culvert was left in place. This combination of restraints may lead to inappropriate movements at the 11-½ degree bend.

5. No information as to the behaviour of the pipeline through the course of the winter was forwarded for review by Trow.

Appendix A:

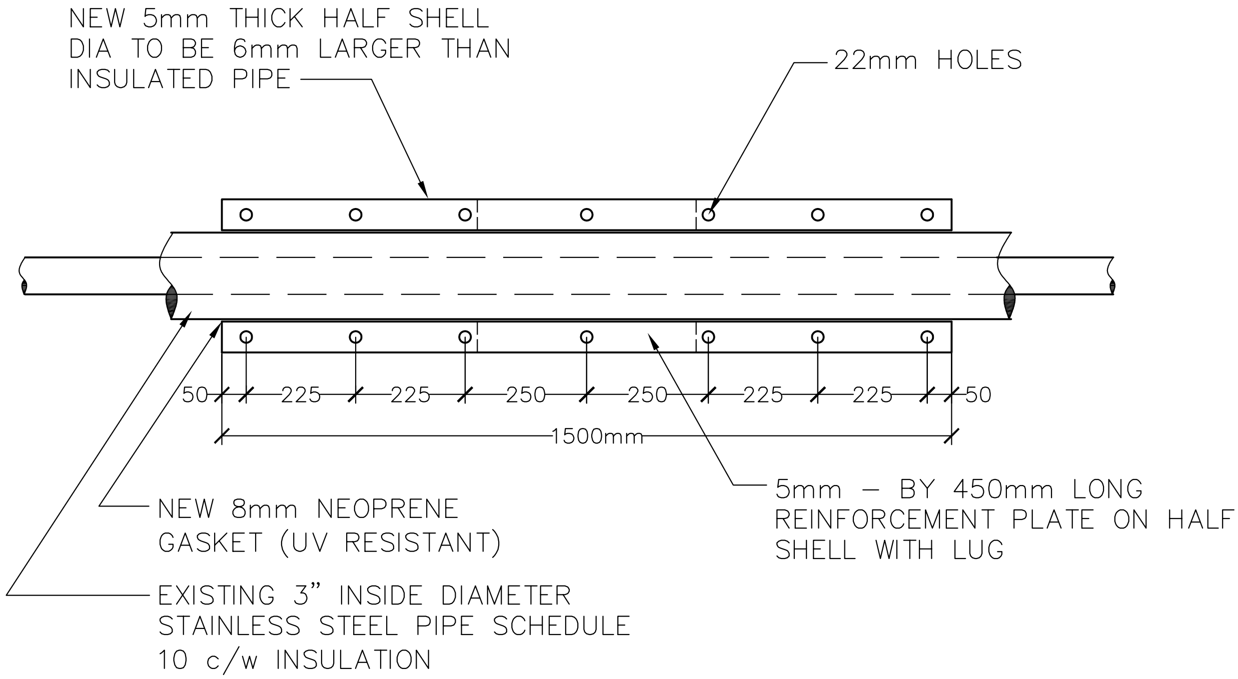
A) SK1: Clamping Sleeve Installation
B) SK2: Clamping Sleeve
C) SK3 Lug Detail for Clamping Sleeve
D) 2004 Program As-built



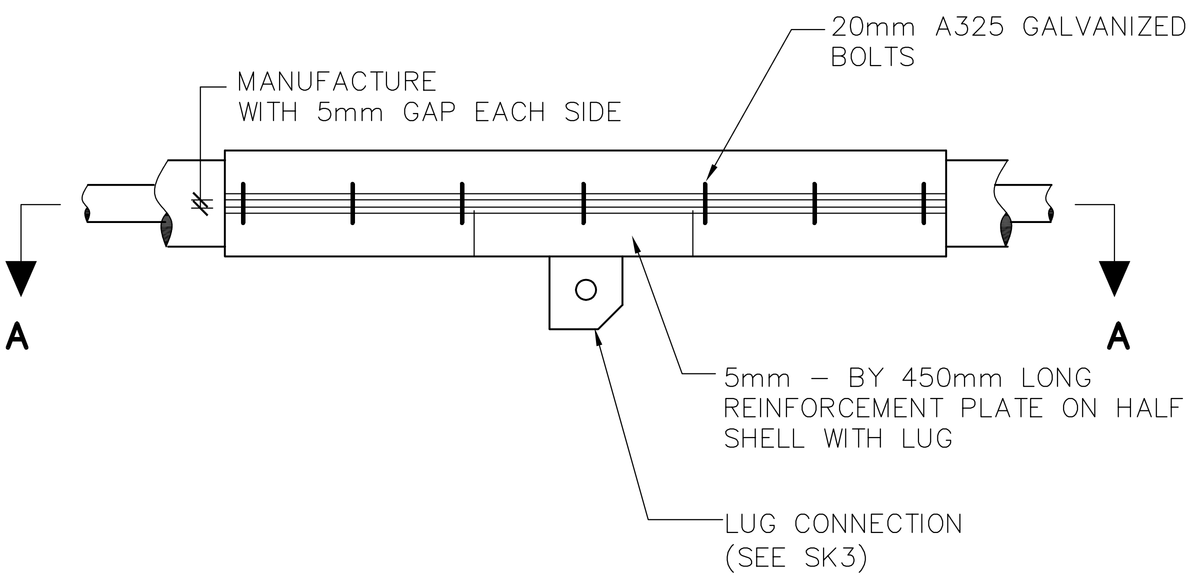
NOTE:
PROVIDE MANUFACTURER'S LITERATURE FOR ACCESSORIES AND DESIRED CONFIGURATION.

Trow Associates Inc.
154 Colonnade Road
Ottawa, Ontario, K2E 7J5
PHONE: (613) 225-9940
FAX: (613) 225-7337

scale: N.T.S.	CLIENT: Cape Dorset Water Main Stabilization	project no.: OTCD00017470A
date: 01/09/04	TITLE: CLAMPING SLEEVE INSTALLATION	SK1
drawn by: I.ORLOVA		



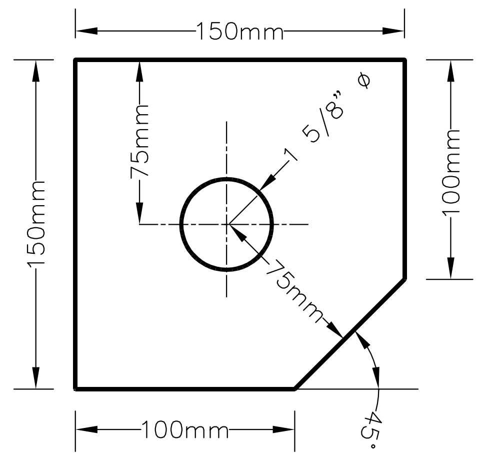
SECTION A–A

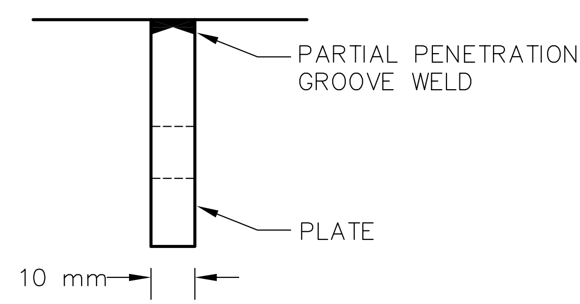


ELEVATION

Trow Associates Inc.
154 Colonnade Road
Ottawa, Ontario, K2E 7J5
PHONE: (613) 225–9940
FAX: (613) 225–7337

scale N.T.S.	CLIENT: Cape Dorset Water Main Stabilization	project no. OTCD00017470A
date 01/09/04		
drawn by I.ORLOVA	TITLE: CLAMPING SLEEVE	SK2





Trow Associates Inc.
154 Colonnade Road
Ottawa, Ontario, K2E 7J5
PHONE: (613) 225-9940
FAX: (613) 225-7337

scale	CLIENT:	project no.
N.T.S.	Cape Dorset Water Main Stabilization	OTCD00017470A
date 01/09/04	TITLE: LUG DETAIL FOR CLAMPING SLEEVE	SK3
drawn by I.ORLOVA		

Trow Associates Inc.

154 Colonnade Road South,
Ottawa, Ontario K2E 7J5

Tel: (613) 225-9940
Fax: (613) 225-7337

Trow Job No. OTCD00017470A

CLIENT	CAPE DORSET WATER MAIN STABILIZATION
TITLE	2004 PROGRAM AS-BUILT

DATE:	SCALE:	DRAWING NO.	REV.
FEB. '05	N.T.S.	SK-4	0

Appendix B:

Memo to File: Phone conversation with General Contractor of 2004 Works

Trow Associates Inc.
154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

Memorandum

Date:	October 19th 2004
Reference:	OTCD00017470
To:	file
cc:	
From:	Barbra Kimmerle
Subject:	**Phone conversation with General Contractor Maurice Fortier for Cape Dorset Watermain rehabilitation program**

The rehabilitation work for 2004 has been completed. The following is a summary as reported by Maurice of the work he did.

- A total of 12 restraints were added to the pipeline.
- One restraint was installed at the heater house at the top of the hill. Weather conditions did not permit the use of any motor vehicle. The contractor attempted to use one of the existing rock anchors to hold the sleeve. We had specified to use a lug on the supports. Since the rock anchors failed, he did have to fix the log nuts onto the support as specified. We had specified a minimum of 4 sleeves at the pump house at 5m intervals.
- A Total of 11 restraints were installed between the Truck Fill Station and the Expansion loop as described below:
  - One (1) restraint was installed immediately below the roadway crossing. We had not specified any for this area.
  - Three (3) restraints were installed between the roadway crossing and the expansion loop along the flatter section of terrain in the vicinity of junction boxes.
  - The remaining seven (7) were installed at approximately 35m intervals on the slope to the expansion loop. One of the restraints was fixed at the lower leg of the expansion loop. We specified 4 sleeves immediately downhill of the expansion loop.
- According to Maurice the pipeline has now been jacked up the hill by approximately 7 ½" as measured at the expansion loop. The lower leg of the expansion loop is square, according to him. The pipeline is no longer touching the edges of the culvert at the road crossing but is centered within it. The jacking of the pipeline seems to have been conducted in a careful manner.

This work is not consistent with the Remedial Measure Procedures sent out to both the Government and the Contractor on September 3rd, 2004.

Trow Associates Inc.
154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
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This work is not consistent with the Remedial Measure Procedures sent out to both the Government and the Contractor on September 3rd, 2004.

2005 Pipeline Stabilization Program
Cape Dorset Water Supply Main
Rehabilitation Review

Prepared for:
Department of Community and Government Services
Government of Nunavut
P.O. Box 379
Pond Inlet, NU X0A 0S0

Trow Associates Inc.

154 Colonnade Road South
Ottawa, Ontario K2E 7J5
Telephone: (613) 225-9940
Facsimile: (613) 225-7337
E-mail: ottawa@trow.com
Web Site: www.trow.com

OTCD00017470A
April 2005

Table of Contents

Appendices

Appendix A:

SK5: Layout Plan 2005 program
SK6: Stainless Steel Pipe Anchor
SK7 Adfreeze Steel Pipe Installation
SK8 Installation of Assembly in Rock
SK9 Insulated Pipe Detail

Appendix B:

Williams Rock Anchor Installation Method and Technical Data

Procedure for Remedial Measures - Spring of 2005

This procedure to be read in conjunction with Sketches, SK-5 to SK-9.

Six (6) stainless steel plate assemblies (see sketch SK-6) are to be installed approximately 5 metre apart along the pipeline downhill of the expansion loop. Refer to Sketch SK-5 for location. These assemblies are to be attached to adfreeze pile foundations as shown in Sketch SK-7.

Four (4) stainless steel plate assemblies (see sketch SK-6) are to be installed approximately 5 metre apart along the pipeline downhill of the Heater House. Refer to Sketch SK-5 for location. These assemblies are to be connected to rock anchors as shown in Sketch SK-8.

Layout locations of piles and rock anchors and placement of stainless steel assemblies along pipeline prior to beginning work to ensure there is no obstruction or interference with the installation at that location.

The following procedure of installation is to be followed:

1. Provide shop drawings of rock anchors, wire rope and all hardware prior to construction for approval.
2. Existing temporary remedial clamped sleeves of Fall 2004 shall be left in place, expect at conflicting locations with permanent sleeves.
3. Drill and install new adfreeze piles as per Sketch SK-7 at specified locations. Ensure that adfreeze piles and 150x10x150 steel plate are centered on pipeline
4. Weld steel cap plate with lug to pipe piles.
5. Drill and install new rock anchors as per Sketch SK-8 and manufacturers instruction at specified locations. Mix grout with warm water (greater than 10ºC). Ensure rock anchors are not cold. Grout rock anchors.
6. Remove pipe jacket and insulation refer to insulation details on Sketch SK-9.
7. Ensure existing stainless steel pipe is clean, dry and undamaged where new stainless steel assemblies are to be installed.
8. Weld the new stainless steel assemblage to pipeline downhill of the two adfreeze piles.
9. Install the ¾ inch diameter cable between the lug of the stainless steel plate assemblage and the adfreeze pipe pile cap plate lug or the rock anchor assemblage. The angle of the cable with respect to the pipeline is not to be greater than 35º. Contractor to confirm to Engineer configuration of cable and accessories utilized. Provide shop drawings for approval.
10. Tighten cables using the turnbuckles.
11. Install insulation around pipeline and new steel assemblage as per SK-9 and SK-….
12. Relocate one of the existing clamped sleeve above the 11 1/2° bend before the culvert to roadway crossing.

13. Provide as-built drawings showing locations of new piles and rock anchors

Materials List for 2005 Stabilization of Pipeline

Anchor to Stainless Steel Pipe

Per assembly (10 required):

- Two Stainless Steel angles each < 100x75x13 LLV each 250mm long
- One Stainless Steel Stiffener plate 10x58x350
- One Stainless Steel Plate 10x250x370
- One Stainless Steel lug 10x150x150
- 400 millimetre diameter insulation (wrap) jacket
- Electrodes for welding stainless steel
- Welding unit

Piles

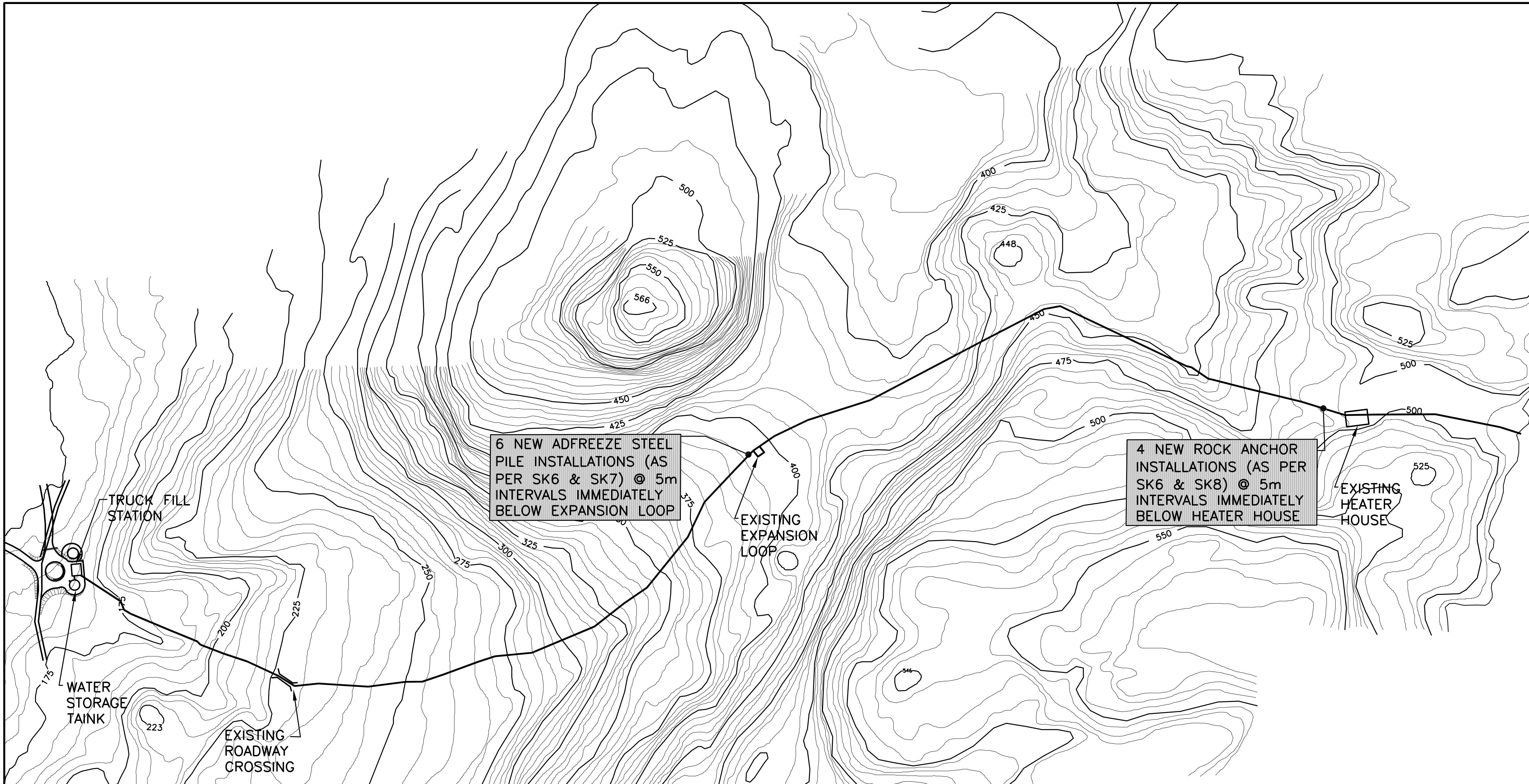
- 12 – 141 millimetre diameter schedule 80 adfreeze piles 9 metre in length
- 6 – 25 millimetre steel plate 1500x300
- 6 – Steel lugs 10x150mmx150 mm
- Electrodes for welding structural steel
- Welding unit

Rock Anchors

- Williams Dome Flight Spherical washer RH108 D20 complete with eyenuts and locknuts
- Compressor for drilling holes

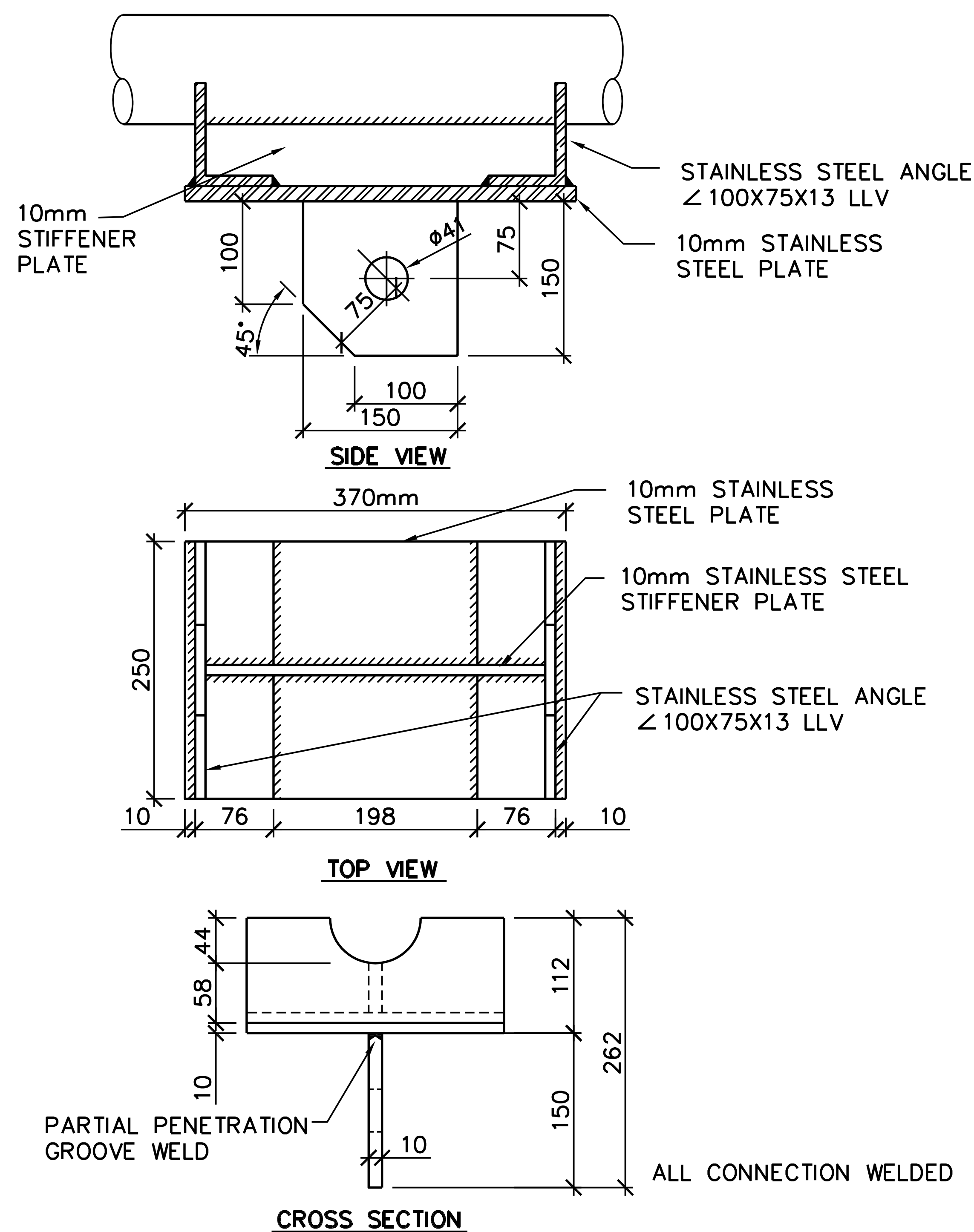
Appendix A:

SK5: Layout Plan 2005 program
SK6: Stainless Steel Pipe Anchor
SK7 Adfreeze Steel Pipe Installation
SK 8 Rock Anchor Installation
SK 9 Insulated Pipe Detail



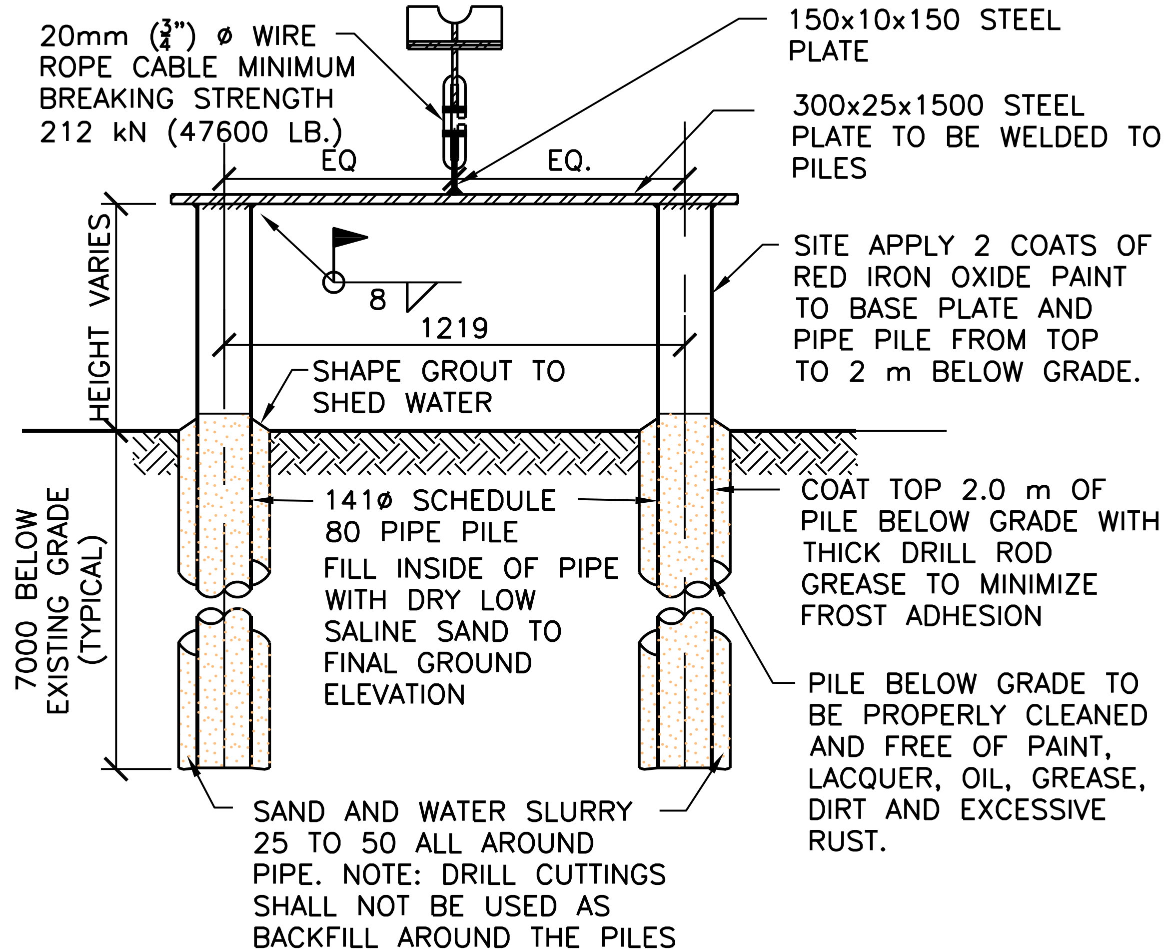
NOTE:
EXISTING CLAMPED SLEEVES ARE TO REMAIN IN PLACE UNLESS IN CONFLICTING LOCATIONS WITH PROPOSED PERMANENT ANCHORS.

Trow Associates Inc. 154 Colonnade Road South, Ottawa, Ontario K2E 7J5 Tel: (613) 225-9940 Fax: (613) 225-7337 Trow Job No. OTCD00017470A	CLIENT	CAPE DORSET WATER MAIN STABILIZATION			
	TITLE	LAYOUT PLAN 2005 PROGRAM	DATE: FEB. '05	SCALE: N.T.S.	DRAWING NO. SK-5 REV. 0



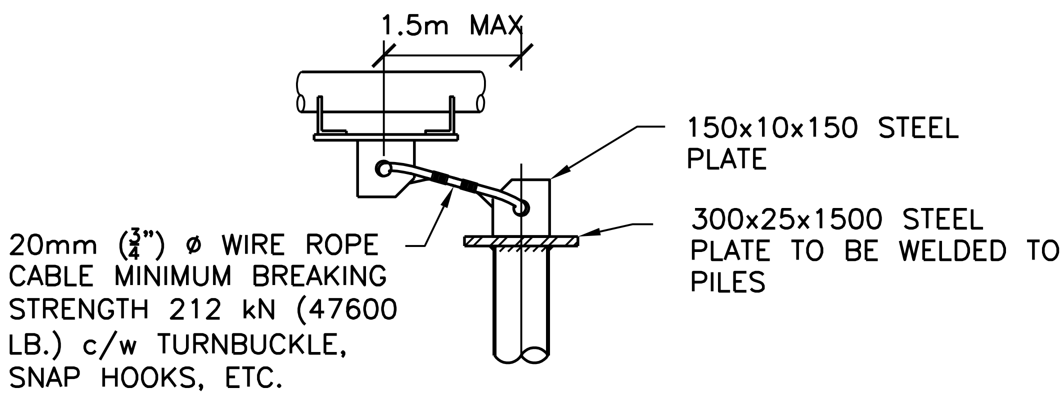
Trow Associates Inc.
154 Colonnade Road
Ottawa, Ontario, K2E 7J5
PHONE: (613) 225-9940
FAX: (613) 225-7337

scale N.T.S.	CLIENT: CAPE DORSET WATER MAIN STABILIZATION	project no. OTCD00017470A
date FEB. '05		
drawn by I.ORLOVA	TITLE: STAINLESS STEEL PIPE ANCHOR	SK-6



ADFREEZE STEEL PILE INSTALLATION

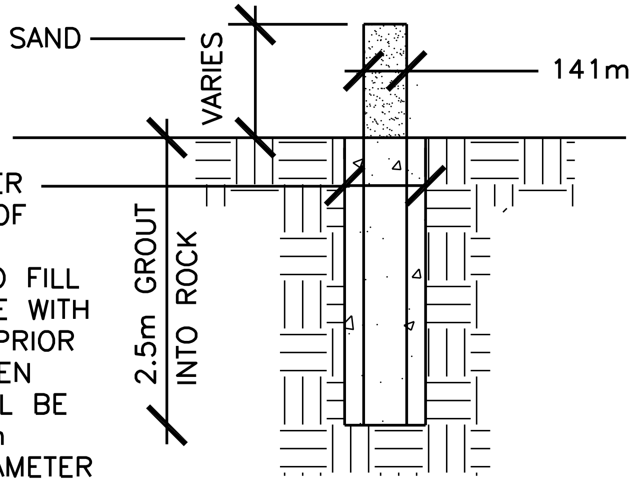
6 ASSEMBLAGES REQUIRED



Trow Associates Inc.
Ottawa, Ontario, K2E 7J5
154 Colonnade Road
PHONE: (613) 225-9940
FAX: (613) 225-7337

scale N.T.S.	CLIENT: CAPE DORSET WATER MAIN STABILIZATION		project no. OTCD00017470A
date FEB. '05			
drawn by M.N.	TITLE: ADFREEZE STEEL PILE INSTALLATION		SK-7

FILL INSIDE OF PILE WITH SAND TO TOP OF PILE.

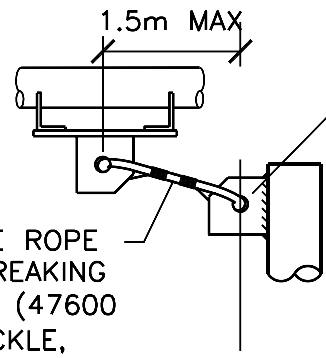


DRILL HOLE, 50mm LARGER THAN OUTSIDE DIAMETER OF STEEL PILE. IF IT IS NOT CONSIDERED PRACTICAL TO FILL ABOUT HALF OF THE HOLE WITH SIKA ARCTIC 100 GROUT PRIOR TO PLACING THE PILE, THEN THE HOLE DIAMETER SHALL BE IN THE ORDER OF 100mm LARGER THAN OUTSIDE DIAMETER OF STEEL PILE TO FACILITATE GOOD GROUT PLACEMENT.

TYPICAL INSTALLATION OF STEEL PILE SOCKETED INTO SOUND BEDROCK

PREDRILL OVERSIZED HOLES 2.5M INTO SOUND BEDROCK.

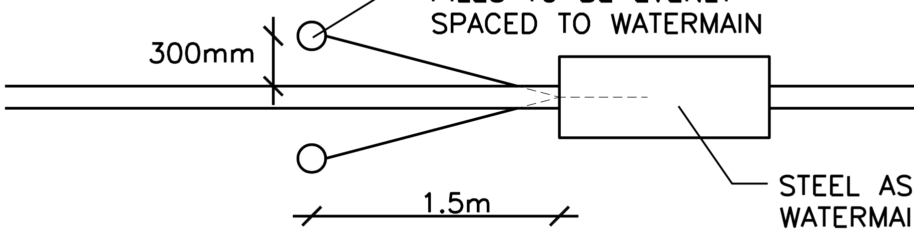
FILL DRILLED HOLE WITH APPROVED FAST SETTING ARCTIC GROUT INTO CLEAN SOCKET. PLACE THE PILES INTO THE GROUT AND VIBRATE TO THE BEDROCK SURFACE.



LUG PLATE TO BE WELDED TO PILE

20mm ($\frac{3}{4}$") ø WIRE ROPE CABLE MINIMUM BREAKING STRENGTH 212 kN (47600 LB.) c/w TURNBUCKLE, SNAP HOOKS, ETC. SHOP DRAWINGS TO BE APPROVED PRIOR TO INSTALLATION.

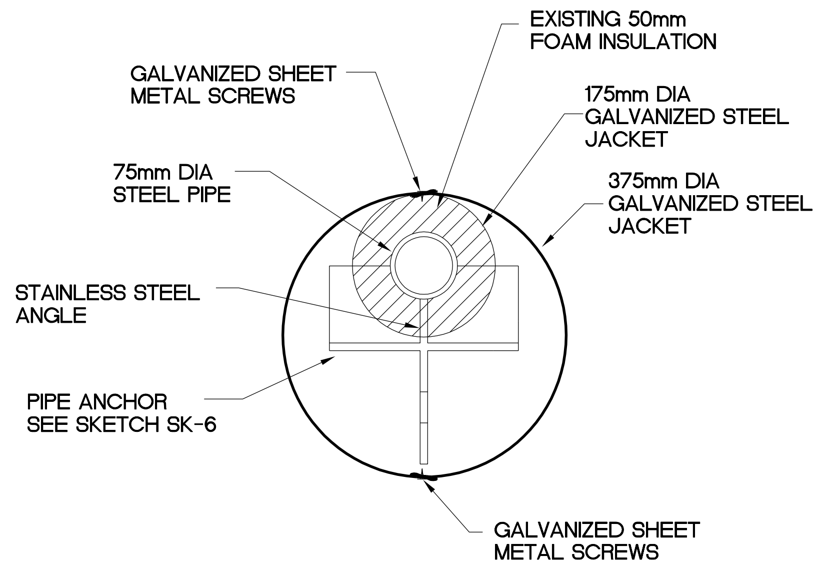
PILES TO BE EVENLY SPACED TO WATERMAIN



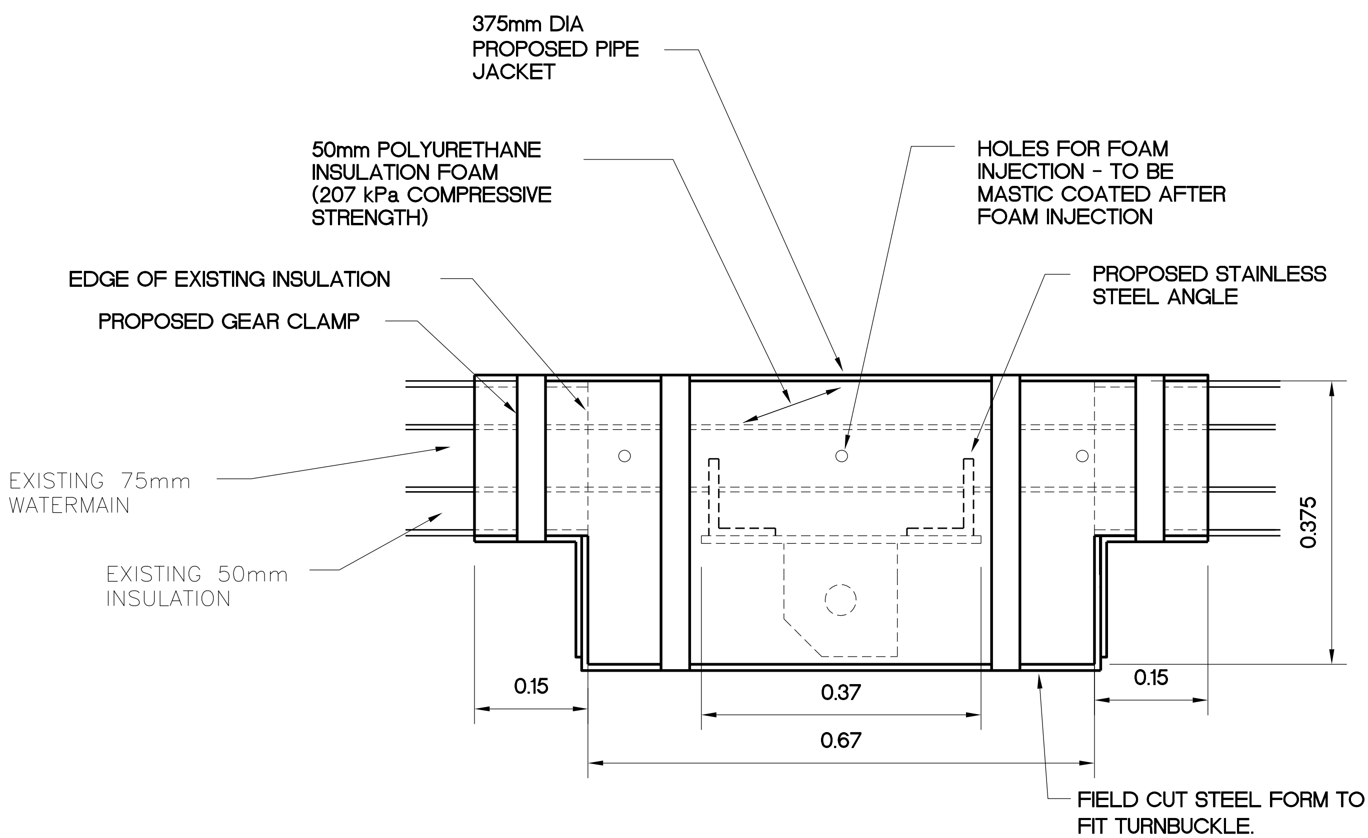
STEEL ASSEMBLY ON WATERMAIN

Trow Associates Inc.
P.O. Box 6
Iqaluit, Nunavut X0A 0H0
PHONE (867) 979-5914
FAX (867) 979-3407

scale N.T.S.	CLIENT: TOWN OF CAPE DORSET	project no. OTCD00017470A
date 25/02/05	TITLE: INSTALLATION OF ASSEMBLY IN ROCK	SK-8
drawn by MR ROULEAU		



INSULATED PIPE - END SECTION



INSULATED PIPE - SECTION

Trow Associates Inc.
P.O. Box 6
Iqaluit, Nunavut X0A 0H0
PHONE (867) 979-5914
FAX (867) 979-3407

scale 1:10	CLIENT: TOWN OF CAPE DORSET	project no. OTCD00017470A
date 25/02/05		
drawn by MR ROULEAU	TITLE: INSULATED PIPE DETAIL	SK-9

Appendix B:
Williams Rock Anchor Installation
Method and Technical Data

FORM HARDWARE & ROCKBOLT (CANADA) LTD.

Installation method for Williams #8 (1") hollow all thread bars using bail type anchors.

Basic Installation

The Williams all-thread-bar rock anchor supplied with a bumped nut and bail type anchors will quickly set and tension using only an impact gun.

The bumped nut allows the bar to spin in the hole engaging the anchor head against the side of the hole. The anchor is normally hung in the hole by the nut resting against the plate.

An impact gun coupled onto a spin adapter (long fitting tool adapter) is used to turn the bumped nut. (Remember that the bumped nut may require a socket hex about 1/16" larger than the normal standard hex nut used on the bar.)

Once the torque resistance of the engaging anchor head rises above about 30 ft. lb., the nut will turn down the bar and lodge against the plate. It should be remembered that it takes very little torque to initially set the bail type anchor in the hole, (about 20 to 30 ft. lb.). The final setting or lock up of the anchor is achieved by torquing the nut against the plate

Further torque will turn the nut down the threads, pulling the anchor cone into the shell. Maximum torque that should be applied is 600 ft. lb. This should equate to about 30,000 lb. of tension in the bar. The bar should have some sort of grease on the threads to ease the torque build-up. Williams has found that CTC Motomaster Extreme Pressure Synthetic grease is very good at reducing the friction build up.

Pretensioning

Additional load can be applied to the anchor bolt using a hydraulic jack, however, if this route is to be chosen, subtle changes in the installation technique must be undertaken at the onset of the installation for anchors positioned vertically downwards.

In these installations the above method leaves very little projecting thread above the nut. There is normally not enough projecting length for a coupling to be used to tension the anchor with a hydraulic jack.

At the start of the installation, instead of just hanging the anchor bolt with the nut against the plate, lift the plate and bolt up and support them on twin, parallel, short sections of 4X4. Commence installation as above, but once the shell starts to set, the supports are removed. The plate will fall to the rock surface leaving the bar projecting some 3.5" high. The installation proceeds as above.

The bumped nut is then run down the bar to the plate with the impact gun/spin adapter in the normal method. Torque the bumped nut as above. The final projection of the top of the bar should be sufficient to fully engage a coupling for the pretensioning operation.

FORM HARDWARE AND ROCKBOLT (CANADA) LTD.

670 INDUSTRIAL ROAD
LONDON, ONTARIO N5V 1V1
PHONE: (519) 659-9444
SALES FAX: (519) 659-5880
ADMIN. FAX: (519) 659-3623
1-800-265-3322

The use of Constant Torque Nuts to Rapidly Set Anchors and the Method of Determining Torque – Tension Relationship On site

The installation time of certain types of mechanical anchors can be greatly reduced by using a constant torque (or bumped) nut which, once attached to the outer end of the anchor rod, will allow the assembly to be spun in the hole until the anchor locks in place. The torque required to turn the rod will start to increase when the anchor locks in place

The nut spins down the threads until it lodges against the plate, once the torque exceeds the preset limit of the nut's torque resistance.

Continued rotation of the nut against the plate will induce a gradual increase of tension into the anchor rod and also draw the anchor cone tighter into the anchor shell which further improves its holding capacity. Eventually the cone and shell lock in place and the anchor rod can be tensioned to a predetermined level of tension using the impact gun initially and finalized with a torque wrench, if required.

This entire operation typically takes only a minute or so when a suitable sized impact gun is used. (approx. 2000 ft-lb. cap)

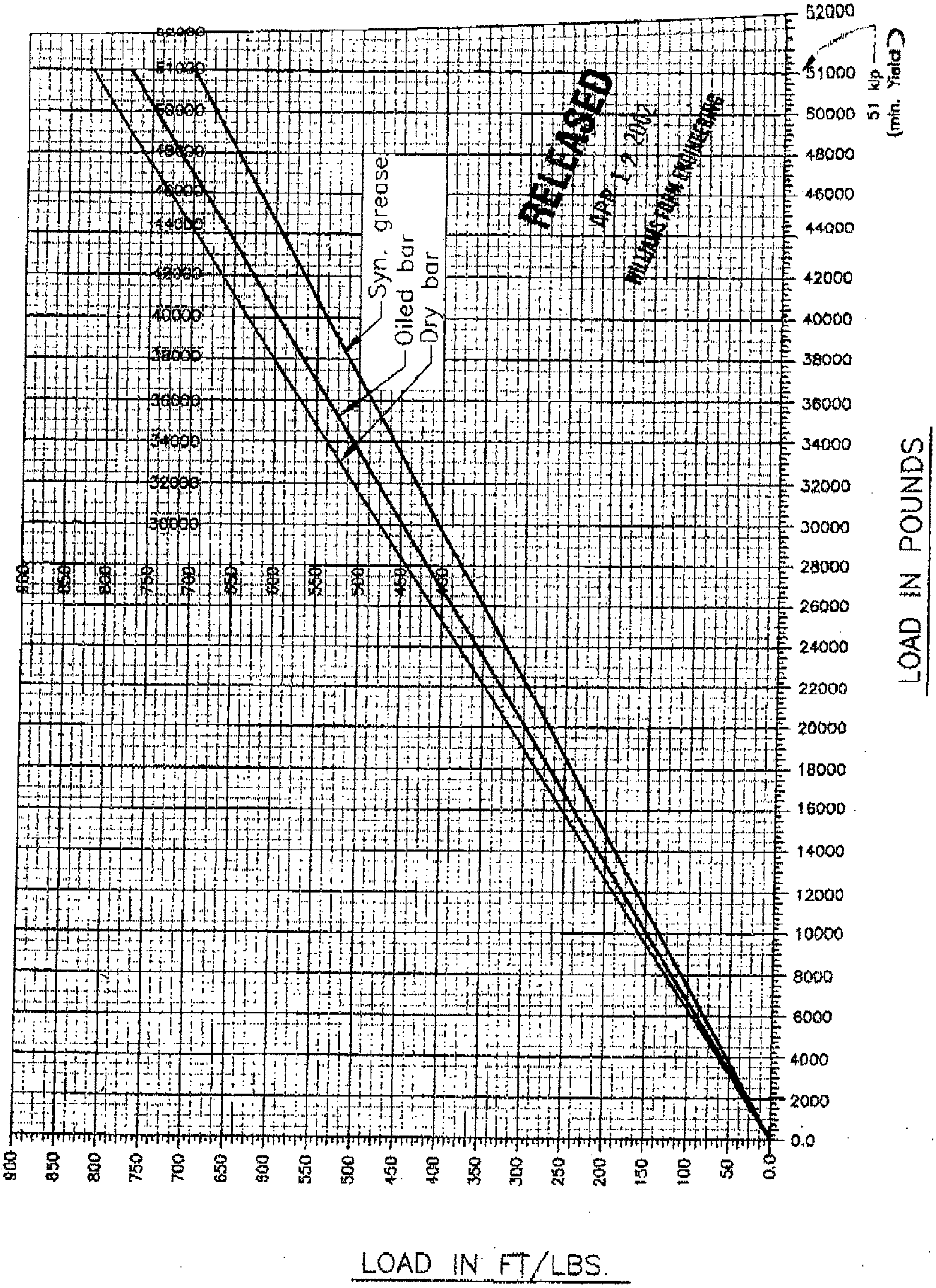
Good correlation is possible between applied torque and tension in the bar. The type of lubrication used on the threads and thread form has a significant affect on this relationship.

The torque-tension relationship is easily determined at the commencement of the project. The anchors are set and torqued to a certain level. Then, by using a hydraulic jack, the anchor rod is loaded until the nut just starts to turn when a weak turning force is applied to the nut by hand with a wrench. This will indicate roughly the relationship between torque and tension. Adjustments to the applied torque are made until the required tension capacity is achieved.

Several iterations of these procedures will be required to get the numbers to closely repeat. Once the relationship has been achieved the hydraulic jack can be used sparingly as a check, say 1 in 10 or so, and the torque wrench instead as the primary method of checking the tension in the anchor.

#8-5 HOLLOW ALL-THREAD- BAR, TORQUE/TENSION GRAPH TEST

Test 1 -MOTOMASTER - SYNTHETIC, EXTREME PRESSURE GREASE (28-0804-4)
Test 2 -OILED WITH RUST INHIBITOR
Test 3 -DRY BAR.



Bodycote ESSAIS DE MATÉRIAUX CANADA INC. www.na.bodycote-mt.com

121 BOUL. HYMUS, POINTE-CLAIRE, QUÉBEC CANADA H9R 1E6 • TÉL: (514) 697-3273 • FAX: (514) 697-2090

TENSILE TEST RESULTS

CLIENT IDENTIFICATION

Client : Williams Form Hardware and Rockbolt
Canada Ltd.
4936 Kent,
Pierrefonds, QC.
H8Z 2T1
Attention : Claude Farley

Date : July 7, 2004
Client No. : WIL002
P.O. No. 24144
Laboratory No. 04181951

P1 of 1

SAMPLE DESCRIPTION

Material : Rock Bolts, Threaded , with nuts and couplers
5TPI bars, Nuts and couplers

Specimen Identification	Tensile Strength - Kn	Yield Strength - Kn	EL %	R/A %
1	315	255	N/A	N/A
2	319	264	N/A	N/A
3	320	270	N/A	N/A

All ruptures occurred in threaded bars.
All nuts and couplers could be rotated by hand after the test.

COMMENTS

Tested to ASTM F432 and F606
0.2% offset based on 20" between load points

Arnold Silverman
Supervisor, Mechanical Testing

RH1-08 ALL THREAD HOLLOW 5TPI

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This entire operation typically takes only a minute or so when a suitable sized impact gun is used. (approx. 2000 ft-lb. cap)

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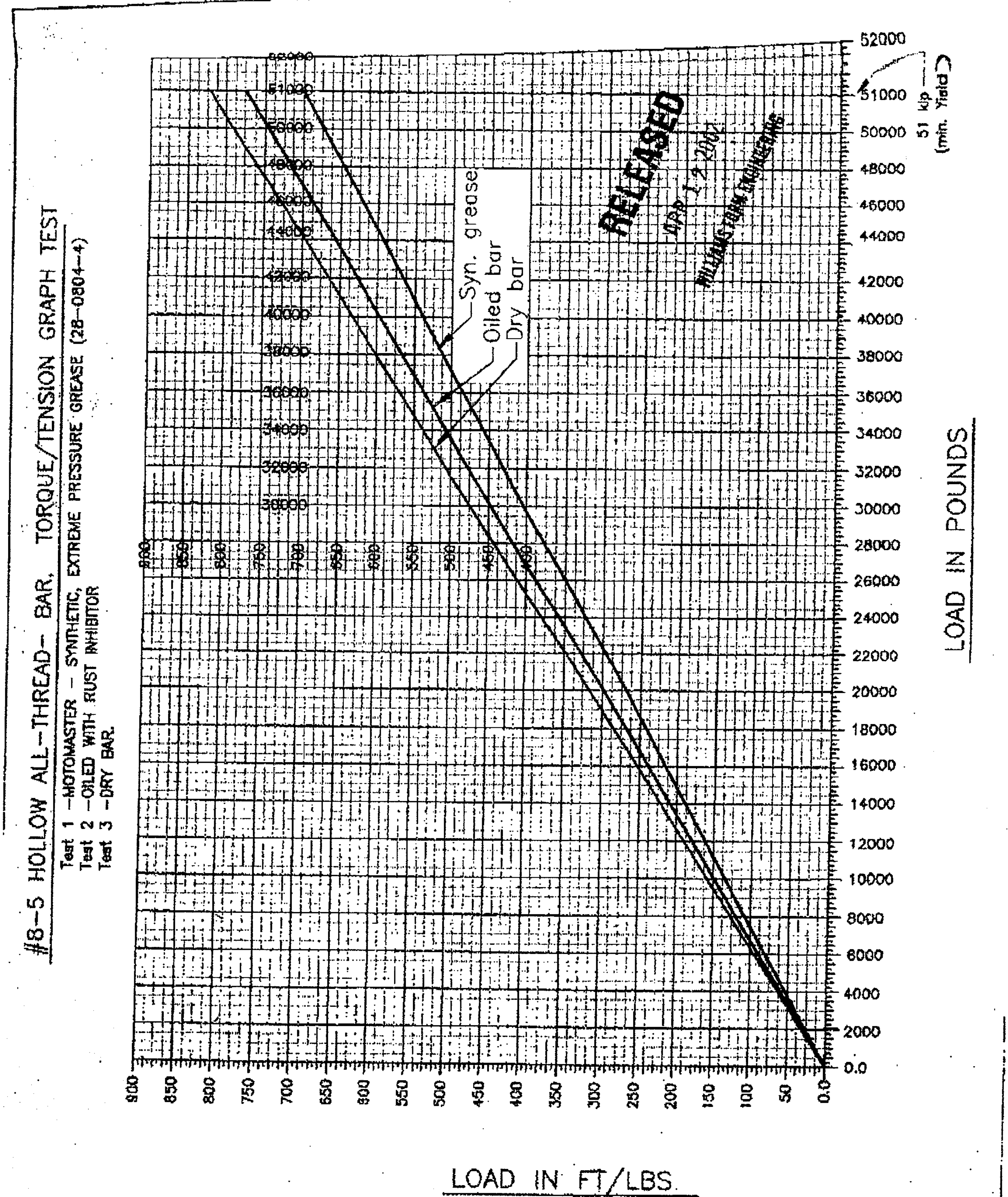

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Test 2 -OILED WITH RUST INHIBITOR
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Syn. grease
Oiled bar
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RELEASED
APR 1 2 2002
WILLIAMS FORM ENGINEERING
51 kip (min. Yield)
LOAD IN POUNDS
LOAD IN FT/LBS.
52000
51000
50000
48000
46000
44000
42000
40000
38000
36000
34000
32000
30000
28000
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22000
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12000
10000
8000
6000
4000
2000
0.0
900 850 800 750 700 650 600 550 500 450 400 350 300 250 200 150 100 50 0.0

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All ruptures occurred in threaded bars.
All nuts and couplers could be rotated by hand after the test.

COMMENTS

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0.2% offset based on 20" between load points

Arnold Silverman
Supervisor, Mechanical Testing

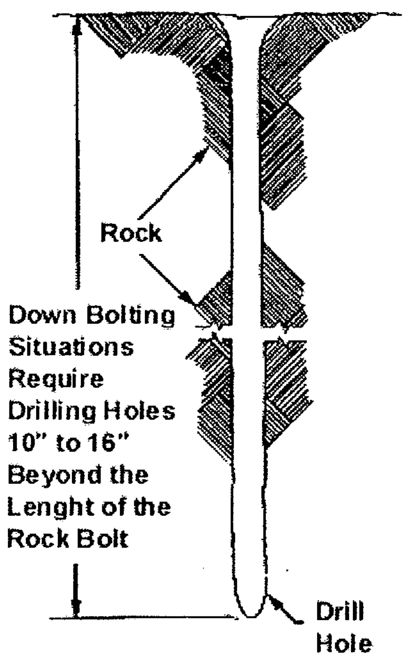
RH1-08   All thread Hollow
5TPI

WILLIAMS FORM ENGINEERING CORP.

Spin-Lock Rock Anchor Installation

Step #1 Drilling

Use Standard Rotary Percussion Equipment



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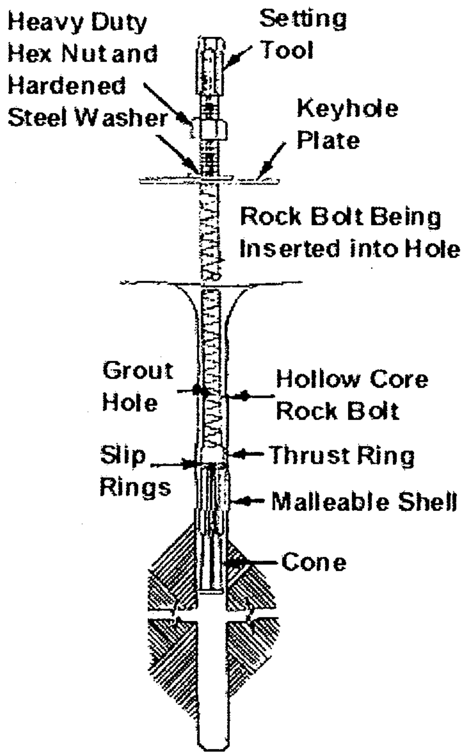
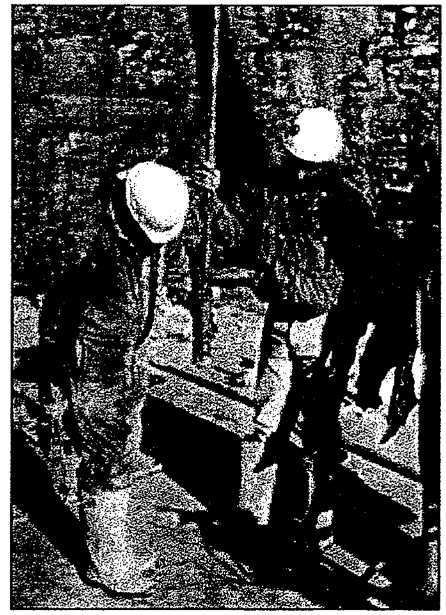
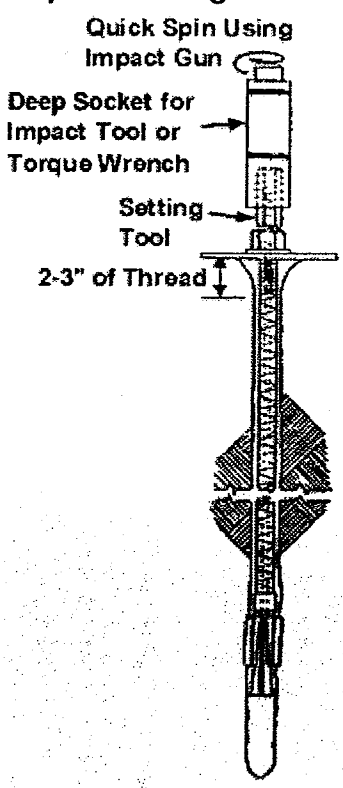
Step #2 Bolt Placement

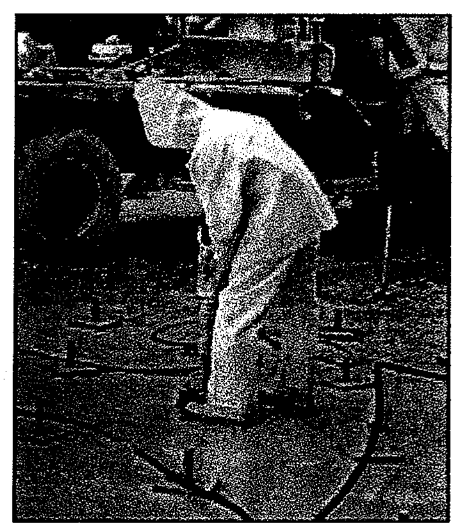




Place the nut, washer, bevel washers (if required), and plate on the rock bolt and push the bolt into the hole to the correct embedment depth. If the bolt becomes stuck in the hole, attach a setting tool to the end of the bolt and drive it into the hole with a sledgehammer.

Step #3 Setting the Anchor

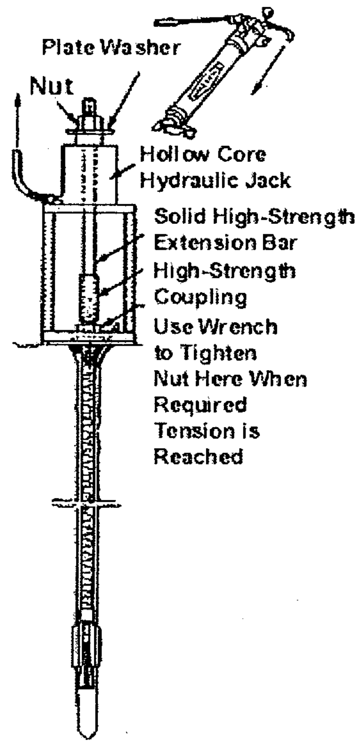


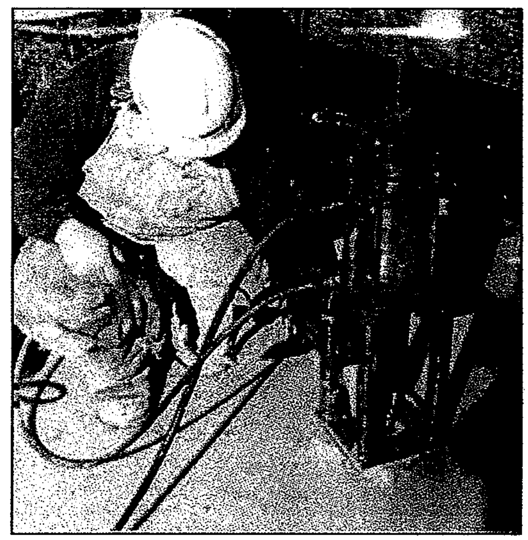


Install setting tool fully onto the exposed threaded end. Provide space between the setting tool and the hex nut. Initially torque the bolt to the required torque with an impact gun, pneumatic, or hydraulic torque wrench. This action migrates the cone into the shell, thus expanding the mechanical anchor into the rock. Final torque can be checked and adjusted with a manual or hydraulic torque wrench. Remove the setting tool by restraining the lower part while rotating it's upper section until the setting tool is loose. Prepare collar area with Williams Wil-Kwik-Set fast setting grout to ensure full bearing under the plate.

Step #4A Testing the Anchor Bolt

Method A - Tensioning with a Test Jack

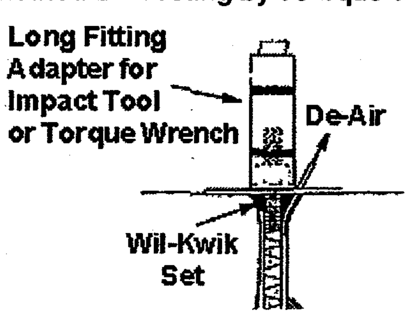


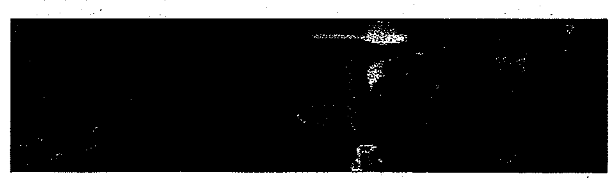


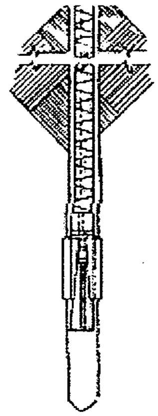
Place the jack and frame over the bolt and attach the test rod and couplings to the bolt. Attach the test nut and test plate over the test rod on top of the jack. Test the rock bolt by tensioning the jack to the required test load (usually half of the ultimate strength) but never exceed the advertised yield strength of the anchor. Adjust the loading of the jack to the required final tension and lock in the final pre-stress load. This is done by tightening the roc bolt hex nut with a knocker wrench (through the frame opening) until a slight reduction is noticed on the jack gauge. The full pre-stress load will be transferred to the anchor bolt onc the tension in the test jack has been released and test components removed.

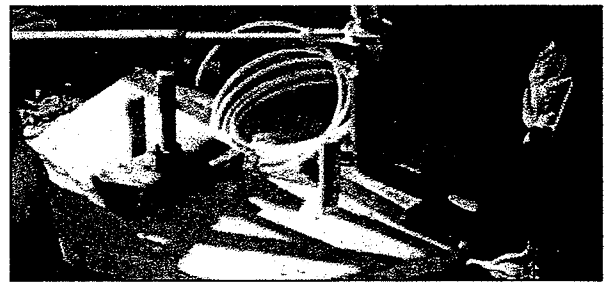
Step #4B Testing the Anchor Bolt

Method B - Testing by Tourque Tensioning



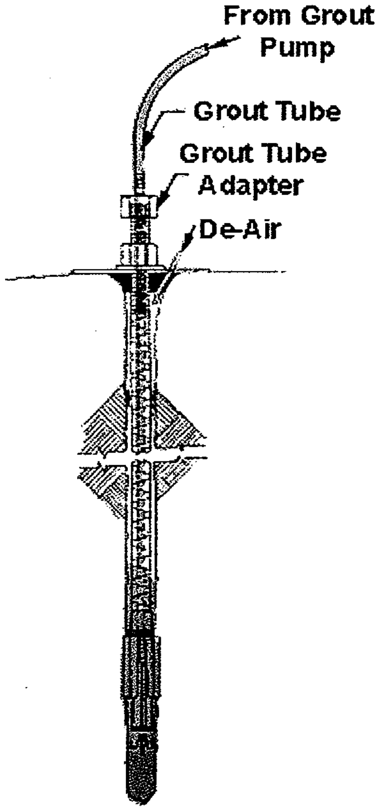






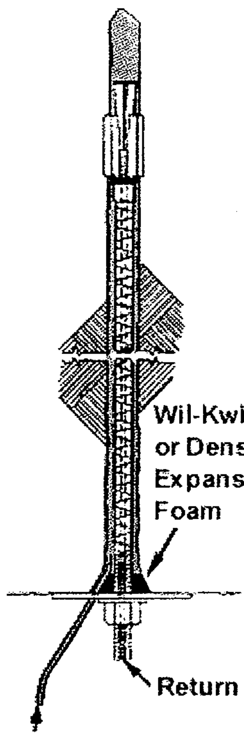
Place plate, bevel washers (if required), hardened washer, and hex nut on the rock bolt. Tension the bolt by torquing the hex nut with a torque wrench. For the recommended torqu valve to obtain the advertised tensile working load, see the "Torque On Nut" column on the Spin-Lock Bolt charts. For other loads, see the torque tension graphs. **Please Note:** The torque/tension relationship is not as accurate as direct tensioning with a hydraulic jack and should not be used where critical tension loads need to be verified.

Step 5: Grouting the Anchor

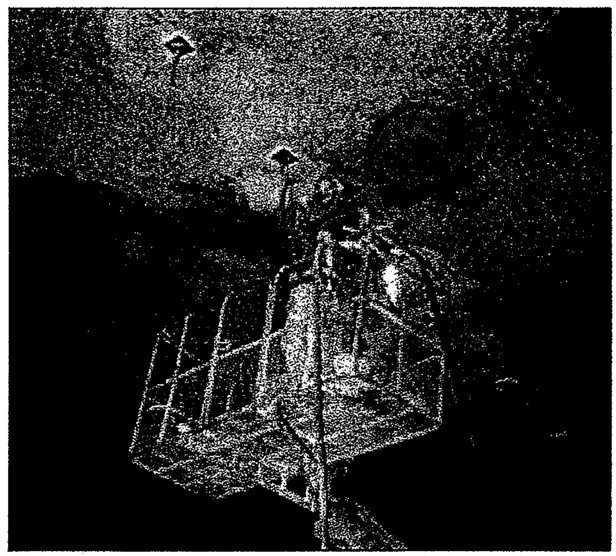


Down Grouting

Always grout from the lowest gravitation point on the anchor bolt until a steady stream of pure grout is seen coming out around the bearing plate or grout tube, and/or from the de-ai tube. For solid bolts, this means that a separate grout tube must be placed in the drill hole (through an opening in the bearing plate) as deep as possible before grouting. Long length solid bolts should have the grout tube attached to the bolt before inserting and setting the anchor. Down-grouting of Hollow Core Rock Bolts can be simply grouted through the hollo core by attaching a grout tube adapter to the outer end of the tensioned bolt and grouting. When the grouting is complete, all air and standing water has been removed from the drill hole by displacement and all cracks and voids in the anchor area are filled with cement grout.



Up Grouting



Up-grouting of Hollow-Core Rock Bolts can be done by grouting through a short length gro tube extending just past the drill hole sealer in the collar area thus using the hollow core at the end of the rock bolt to de-air the hole. Up-grouting of solid rock bolts involves attaching long length grout tube to the anchor (prior to insertion, setting, and tensioning) and groutin through a separate short length tube that extends past the sealer area thus allowing the ro bolt to de-air from the longer grout tube.

Final Thoughts

Williams offers a field installation advising service to aid contractors in the initial installation process of installing all types of anchor bolts. Williams "Spin-Lock Anchor Installation Vide is also available upon request. Contact your Williams sales representative for details.

FORM HARDWARE & ROCKBOLT (CANADA) LTD.

Installation method for Williams #8 (1") hollow all thread bars using bail type anchors.

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The bumped nut allows the bar to spin in the hole engaging the anchor head against the side of the hole. The anchor is normally hung in the hole by the nut resting against the plate.

An impact gun coupled onto a spin adapter (long fitting tool adapter) is used to turn the bumped nut. (Remember that the bumped nut may require a socket hex about 1/16" larger than the normal standard hex nut used on the bar.)

Once the torque resistance of the engaging anchor head rises above about 30 ft. lb., the nut will turn down the bar and lodge against the plate. It should be remembered that it takes very little torque to initially set the bail type anchor in the hole, (about 20 to 30 ft. lb.). The final setting or lock up of the anchor is achieved by torquing the nut against the plate

Further torque will turn the nut down the threads, pulling the anchor cone into the shell. Maximum torque that should be applied is 600 ft. lb. This should equate to about 30,000 lb. of tension in the bar. The bar should have some sort of grease on the threads to ease the torque build-up. Williams has found that CTC Motomaster Extreme Pressure Synthetic grease is very good at reducing the friction build up.

Pretensioning

Additional load can be applied to the anchor bolt using a hydraulic jack, however, if this route is to be chosen, subtle changes in the installation technique must be undertaken at the onset of the installation for anchors positioned vertically downwards.

In these installations the above method leaves very little projecting thread above the nut. There is normally not enough projecting length for a coupling to be used to tension the anchor with a hydraulic jack.

At the start of the installation, instead of just hanging the anchor bolt with the nut against the plate, lift the plate and bolt up and support them on twin, parallel, short sections of 4X4. Commence installation as above, but once the shell starts to set, the supports are removed. The plate will fall to the rock surface leaving the bar projecting some 3.5" high. The installation proceeds as above.

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PHONE: (519) 659-9444
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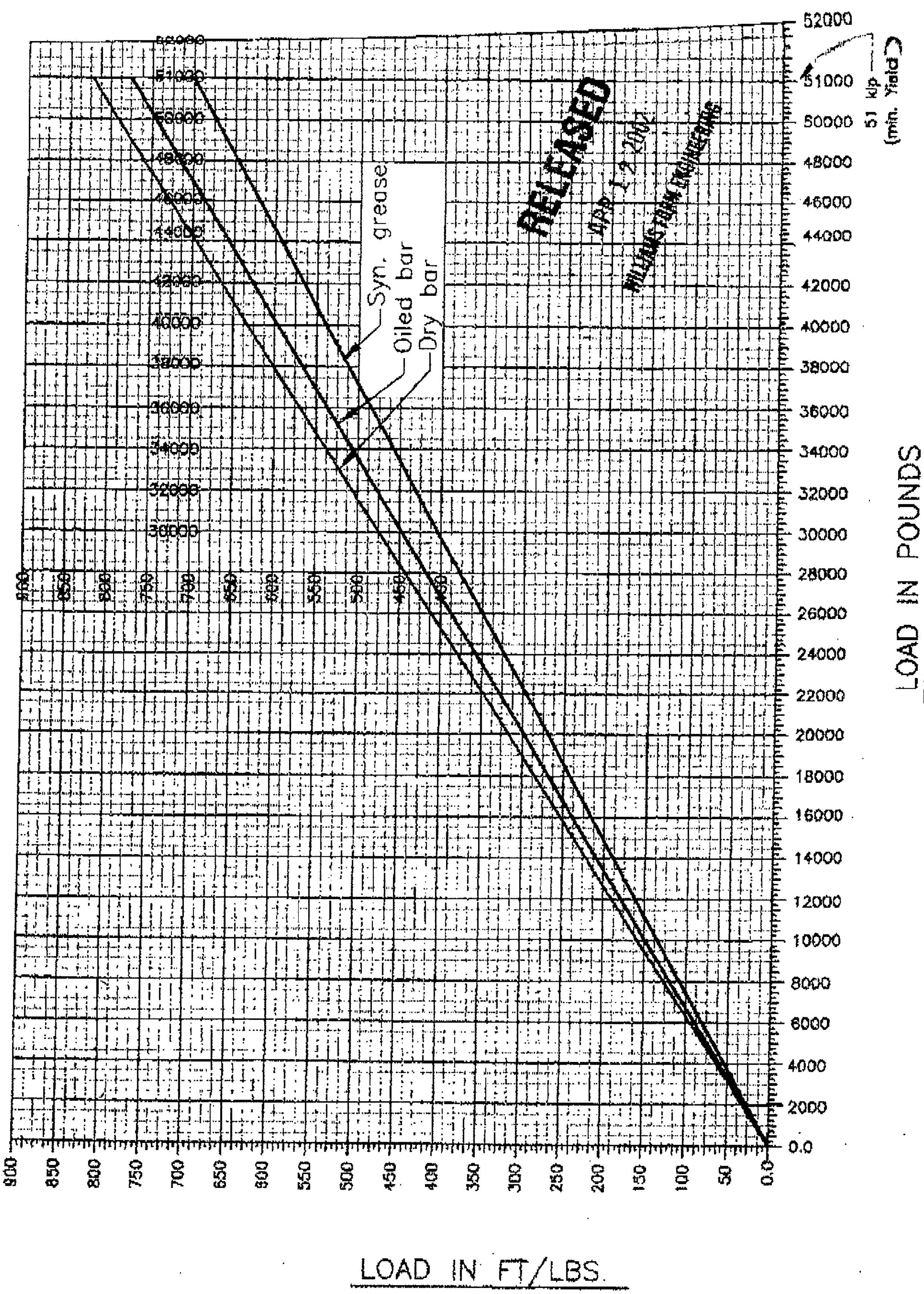

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TENSILE TEST RESULTS

CLIENT IDENTIFICATION

Client : Williams Form Hardware and Rockbolt Canada Ltd.
4936 Kent,
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Attention : Claude Farley

Date : July 7, 2004
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RH1-08 ALL THREAD HOLLOW 5TPI

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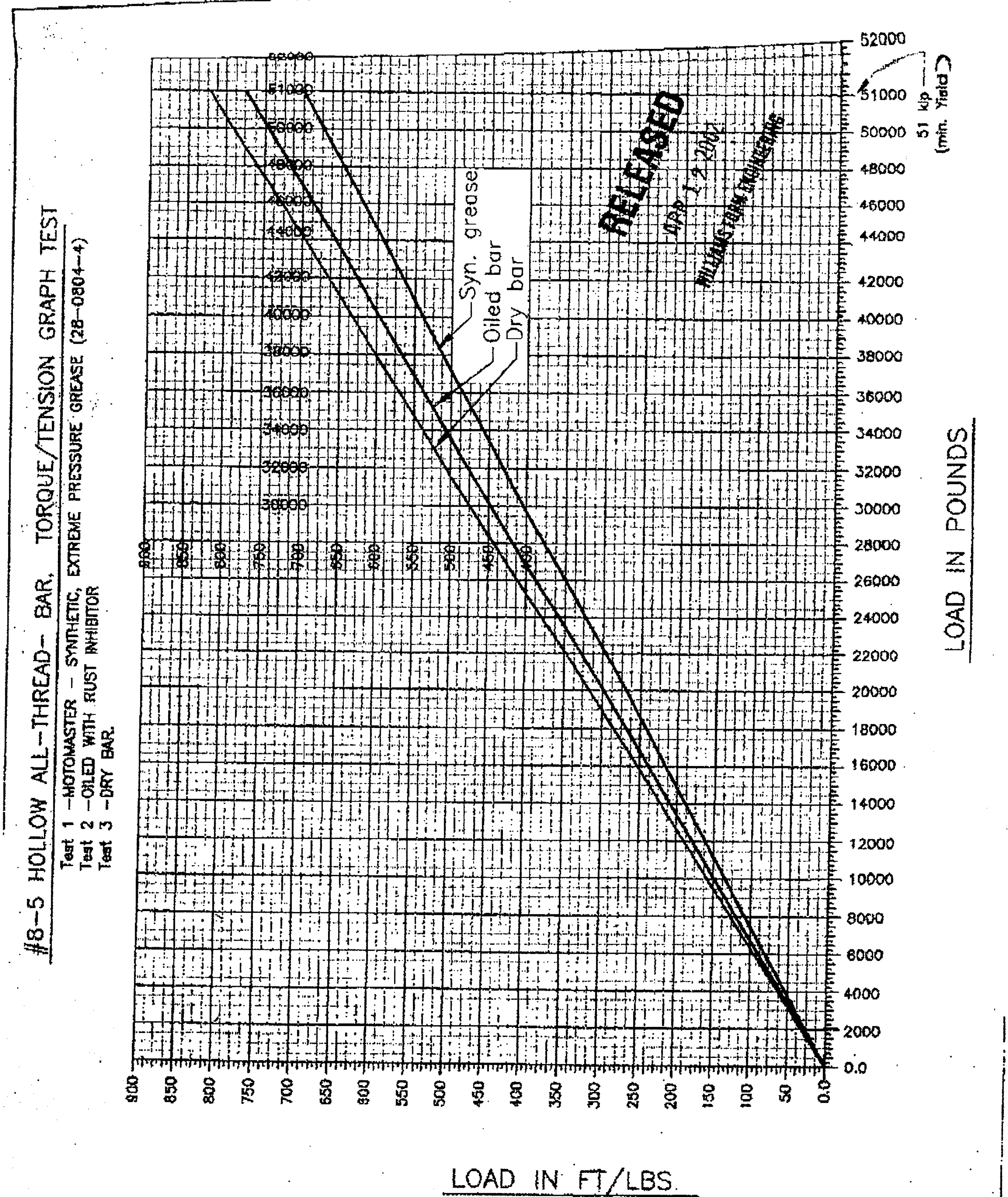

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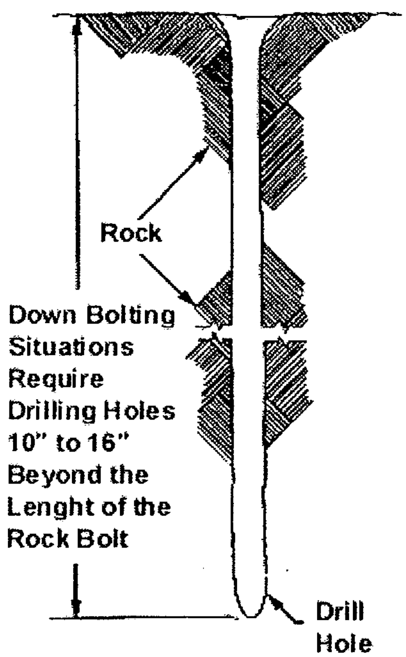

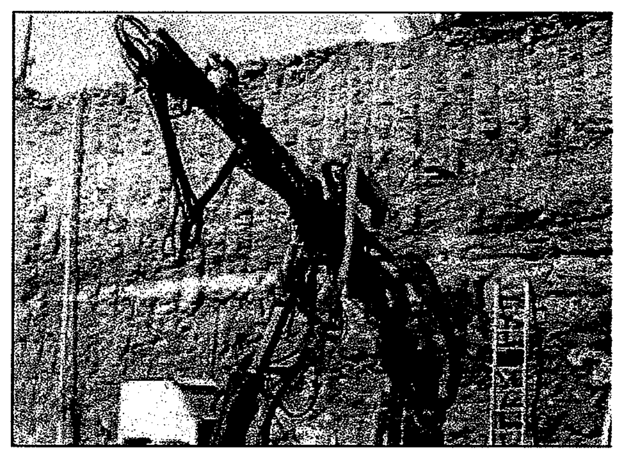

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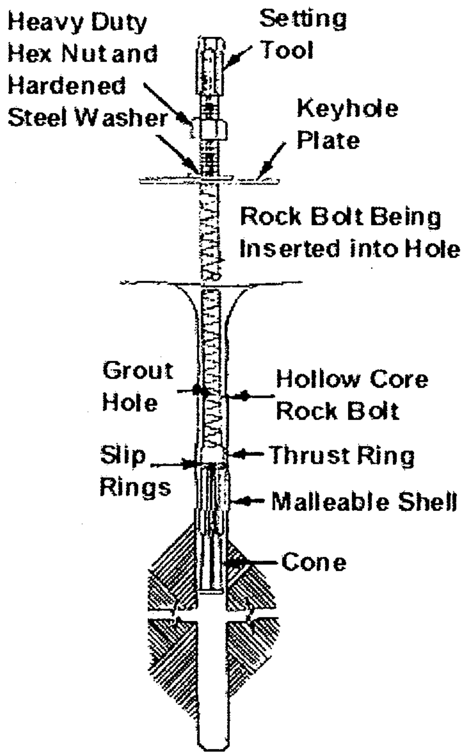

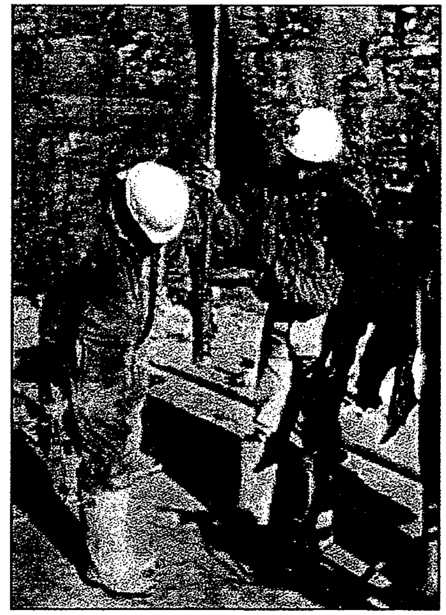

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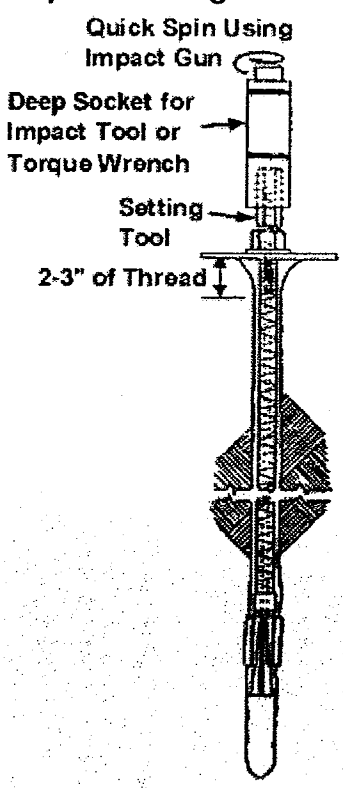
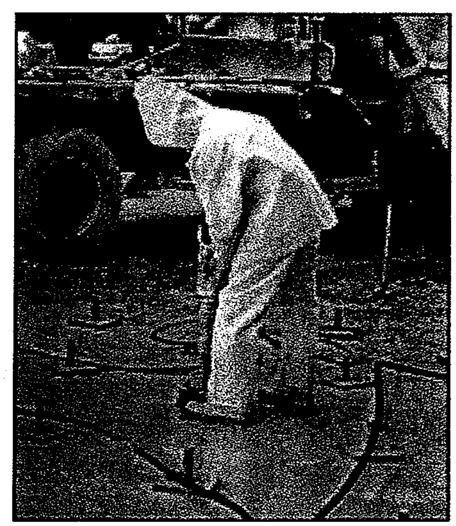
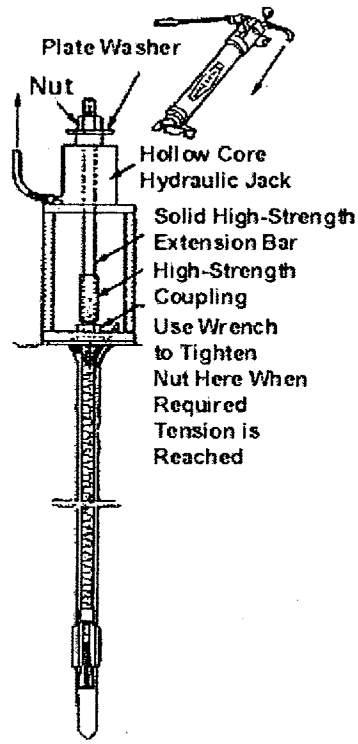


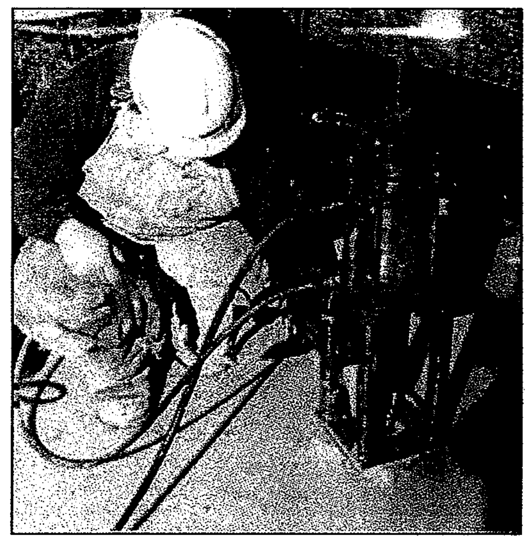


Install setting tool fully onto the exposed threaded end. Provide space between the setting tool and the hex nut. Initially torque the bolt to the required torque with an impact gun, pneumatic, or hydraulic torque wrench. This action migrates the cone into the shell, thus expanding the mechanical anchor into the rock. Final torque can be checked and adjusted with a manual or hydraulic torque wrench. Remove the setting tool by restraining the lower part while rotating it's upper section until the setting tool is loose. Prepare collar area with Williams Wil-Kwik-Set fast setting grout to ensure full bearing under the plate.

Step #4A Testing the Anchor Bolt

Method A - Tensioning with a Test Jack

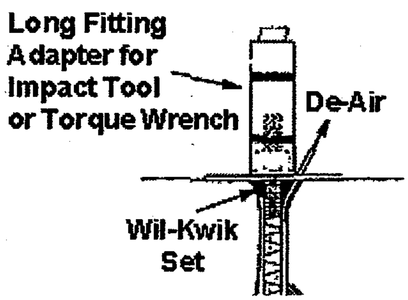


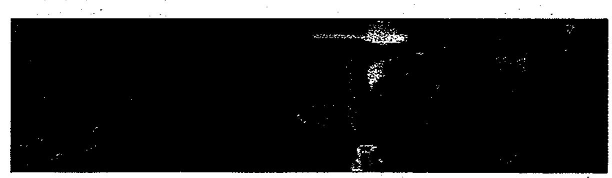


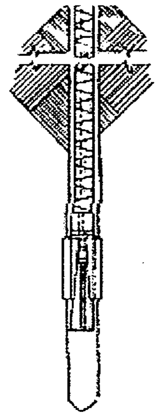
Place the jack and frame over the bolt and attach the test rod and couplings to the bolt. Attach the test nut and test plate over the test rod on top of the jack. Test the rock bolt by tensioning the jack to the required test load (usually half of the ultimate strength) but never exceed the advertised yield strength of the anchor. Adjust the loading of the jack to the required final tension and lock in the final pre-stress load. This is done by tightening the roc bolt hex nut with a knocker wrench (through the frame opening) until a slight reduction is noticed on the jack gauge. The full pre-stress load will be transferred to the anchor bolt onc the tension in the test jack has been released and test components removed.

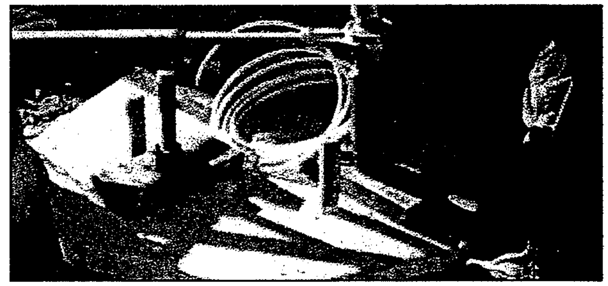
Step #4B Testing the Anchor Bolt

Method B - Testing by Tourque Tensioning



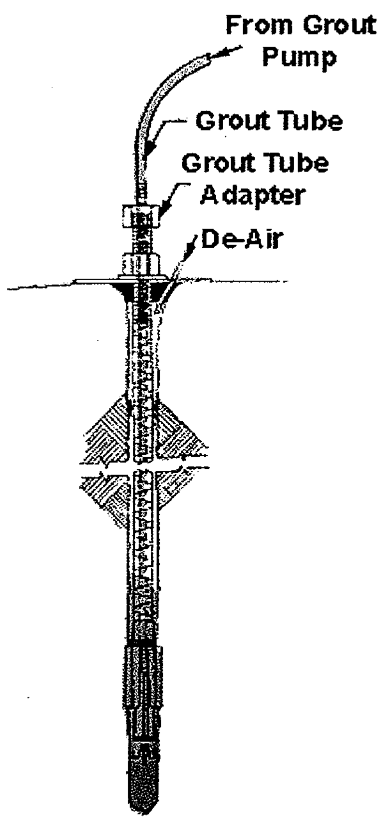






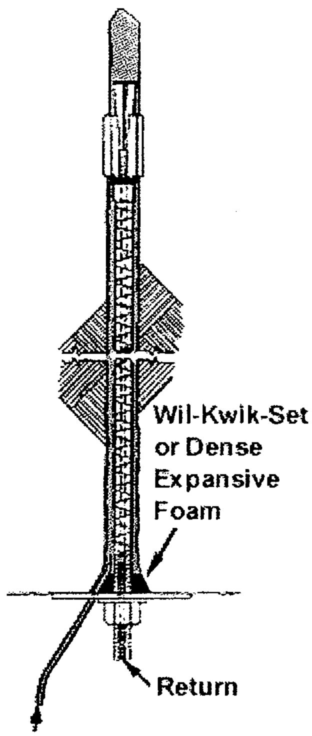
Place plate, bevel washers (if required), hardened washer, and hex nut on the rock bolt. Tension the bolt by torquing the hex nut with a torque wrench. For the recommended torqu valve to obtain the advertised tensile working load, see the "Torque On Nut" column on the Spin-Lock Bolt charts. For other loads, see the torque tension graphs. **Please Note:** The torque/tension relationship is not as accurate as direct tensioning with a hydraulic jack and should not be used where critical tension loads need to be verified.

Step 5: Grouting the Anchor

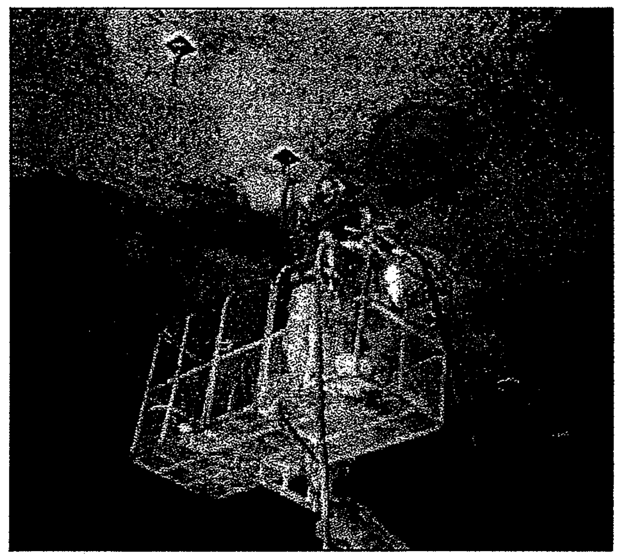


Down Grouting

Always grout from the lowest gravitation point on the anchor bolt until a steady stream of pure grout is seen coming out around the bearing plate or grout tube, and/or from the de-ai tube. For solid bolts, this means that a separate grout tube must be placed in the drill hole (through an opening in the bearing plate) as deep as possible before grouting. Long length solid bolts should have the grout tube attached to the bolt before inserting and setting the anchor. Down-grouting of Hollow Core Rock Bolts can be simply grouted through the hollo\ core by attaching a grout tube adapter to the outer end of the tensioned bolt and grouting. When the grouting is complete, all air and standing water has been removed from the drill hole by displacement and all cracks and voids in the anchor area are filled with cement grout.



Up Grouting



Up-grouting of Hollow-Core Rock Bolts can be done by grouting through a short length groı tube extending just past the drill hole sealer in the collar area thus using the hollow core at the end of the rock bolt to de-air the hole. Up-grouting of solid rock bolts involves attaching long length grout tube to the anchor (prior to insertion, setting, and tensioning) and groutinç through a separate short length tube that extends past the sealer area thus allowing the ro(bolt to de-air from the longer grout tube.

Final Thoughts

Williams offers a field installation advising service to aid contractors in the initial installation process of installing all types of anchor bolts. Williams "Spin-Lock Anchor Installation Videc is also available upon request. Contact your Williams sales representative for details.

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