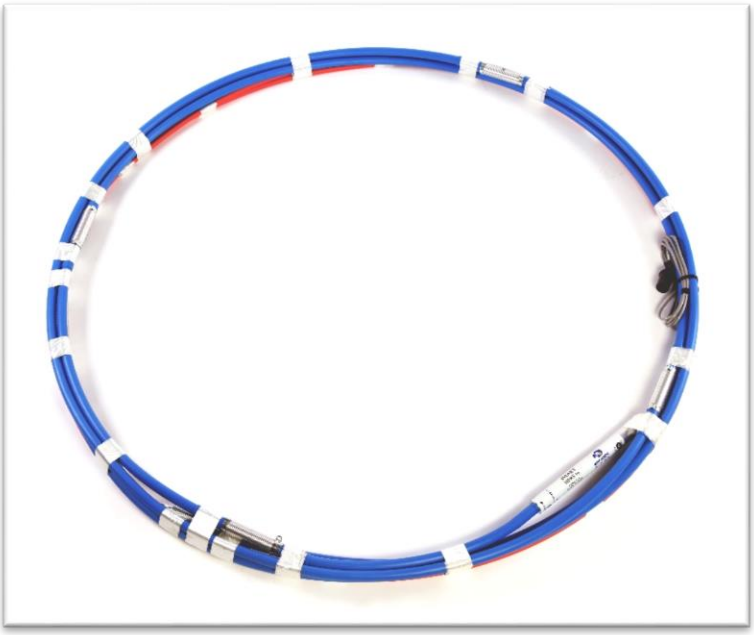
Mine Design technologies

MPBX

Multi-Point Borehole Extensometer

User Guide



SMART MPBX

V2.0 March 22, 2018

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1 About this Document

This document describes the setup procedure, installation and use of the Multi-Point Borehole Extensometer (MPBX).

1.1 Revision Status

Table 1 – Revision Status

Date	Revision	Information
Sep 26, 2014	1.0	Document inception
Jan 10, 2015	1.1	Modified Section 3
Feb 20, 2015	1.2	Entity Parameters
March 01, 2015	1.3	Entity Parameters
March 17, 2015	1.4	Application warning
March 18, 2015	1.5	Section 5 revised
April 27, 2016	1.6	Section 4 revised
Nov 10, 2016	1.7	MT
Jan 16, 2017	1.8	Connector pinout
Sept 19, 2017	1.9	Pinout Table
March 22, 2018	2.0	MT

1.2 Document Approvals

Table 2 – Approvals Status

Date	Revision	Approval
Sep 26, 2014	1.0	Uncontrolled
Jan 10, 2015	1.1	Uncontrolled
Feb 20, 2015	1.2	Uncontrolled
March 01, 2015	1.3	Uncontrolled
March 17, 2015	1.4	Uncontrolled
March 18, 2015	1.5	MT, AD
April 27, 2016	1.6	MT, AD
Nov 10, 2016	1.7	MT
Jan 16, 2017	1.8	MT
Sept 19, 2017	1.9	MT
March 22, 2018	2.0	MT

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2 Introduction

This document describes the installation and use of Mine Design Technologies Inc. (MDT) Multi-Point Borehole Extensometer (MPBX). This document is intended to provide an overview of the installation only. There may be conditions at your operation that require an alternate form of installation, or modifications to this procedure. In such cases, please contact MDT directly for guidance. It is recommended that you read the entire installation procedure prior to starting installation.

3 Description

Each MPBX consists of 4 main components:

1. The MPBX body, which is comprised of up to 6 aluminum anchors separated by blue UV-HDPE tubes. Inside these blue outer tubes is an inner tube comprised of (depending on length) fiberglass or UV-HDPE. Inside this inner tube are up to 6 fiberglass rods that connect each of the anchor nodes to the instrumented head.

2. The instrumented head, a 33mm (1.3") diameter tube containing the electronics for converting the displacements experienced by each of the extensometer rods into a voltage.

3. The lead-wire, which carries both the excitation voltage for the potentiometers and the return voltages registered by each of the anchor positions. To provide protection for the lead-wire, a white UV-HDPE sleeve is used. This also permits the lead-wire to be shotcreted (non-fibre) in place if protection from blast damage is required.

4. The connector, which is used to connect the MPBX to any MDT SMART series instrument readout unit. Specifically, the MPBX can be read with a MDT SMART Reader, a SMART Log or SMART Log3 datalogger, or monitored remotely with a MDT-RTU wireless node across the Newtrax MineHop wireless mesh network. In addition, the MPBX can also be read using a handheld multimeter and reference voltage source. Refer to Sections 9 for installation guidance.

To facilitate shipping of the instruments, MPBX's are coiled on a 1.5m (60") diameter and secured with fibre tape. Each MPBX is individually coiled and taped; the coiled lead-wire is held to the MPBX with tie wraps. For small instrument orders, the MPBX's will be individually wrapped in bubble wrap and plastic, with the entire order held together with a plastic wrap. Larger instrument orders are shipped to site in a protective shipping crate.

It's recommended that you keep the MPBX's in the protective wrap or shipping crate until you are ready to install them. If you are installing multiple MPBX's at the same location and your facilities allow it, you may wish to consider moving all of the MPBX's to the installation site in the protective wrap or shipping crate.

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4 Theory of Operation

An MPBX is a displacement based sensor. There are up to 6 points of measurement, one at each anchor, referenced to the instrumented head. As each anchor moves, fiberglass rods within the MPBX produce a very precise change in resistance at the wiper terminals. This resistance change is converted to a voltage, relative to a reference voltage. The displacement is calculated as a ratio of these data. The displacement data from each anchor is interpreted, and rock movement mapped.

4.1 Displacement Calculation - Voltage

In its simplest form, displacement is calculated as a ratio of voltages and is the delta between the readings at installation (baseline) vs the current readings.

As a ratio of voltages:

$$Delta\ Displacement\ (mm) = \frac{[Current\ Reading\ (volts) - \ Baseline\ Reading\ (volts)]}{[Reference\ Reading\ (volts)\ \div\ PotLength\ (mm)]}$$

$$Delta\ Displacement\ (inch) = \frac{[Current\ Reading\ (volts) - \ Baseline\ Reading\ (volts)]}{[Reference\ Reading\ (volts)\ \div\ PotLength\ (inch)]}$$

For instance, a reference voltage of 5.0 volts is used to excite the potentiometer. The resultant wiper voltage (current reading) for anchor 1, as measured with a multimeter, is 1 volt. At the time of installation (baseline reading) the wiper voltage was 0.3 volt. For a 127mm (5" MPBX the displacement would calculate to be 17.78 mm (0.7"). A positive result signifies that the MPBX is growing in length (extension). A negative sign signifies contraction or compression.

This process is repeated for the remaining 5 anchors. In this fashion, details of rock movement vs depth can be mapped.

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5 Decoding Your MPBX

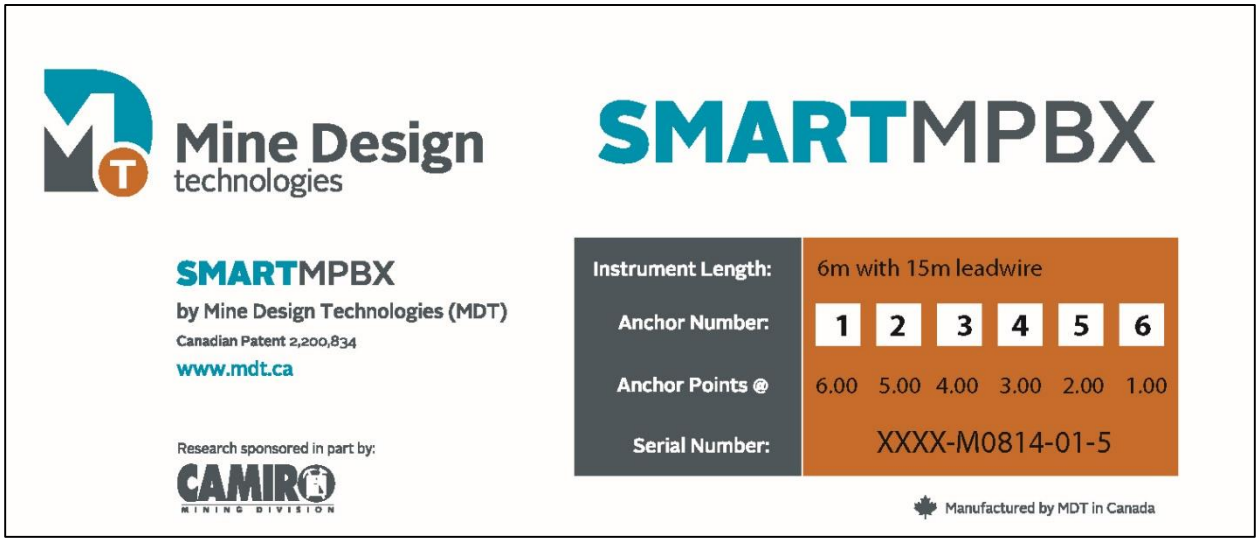
Each MPBX is custom built to order dependent on the installation location. The following example is that of a typical instrument label.

Instrument Length: In this example the MPBX overall length is 6m (20') and comes with 15m (49') of leadwire (5m (16') is always left unprotected, and the remaining 10m (32') covered in protective white UV-HDPE tube).

Anchor Number/Points: It is important to know that anchor #1 is the anchor furthest away from the instrumented head (the head has the 33mm (1.3") aluminum tube with the below sticker attached). From the label we can see that each of the 6 anchors are spaced equally apart at a distance of 1m (39").

Serial Number: The first 4 characters 'XXXX' represent the client code. 'M' defines the instrument type; an MPBX. '0814' represent the month and year the MPBX was manufactured. '01' is the number of instruments manufactured for a specific client that month. '5' represents the maximum displacement the MPBX is designed to measure; in this case 5" (127mm). Other standard displacement options include, but not limited to, 63.5mm (2.5"), 254mm (10"), 305mm (12") and 508mm (20").

Figure 1 – Identification Label



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6 Check Your Boreholes!

It has been the experience of MDT that the number one cause for delays during any geotechnical instrument installation is inadequate co-ordination between parties. Though the installation of an MPBX is straightforward there are a number of key steps that must occur prior to installation. They are:

1. Clearly identifying the borehole. It's not uncommon for there to be many boreholes drilled at any one intersection. If the borehole for the MPBX is not identified it can be a matter of several hours of effort to determine which borehole was the one drilled long enough for the MPBX to be installed into.

2. Check to ensure the intended MPBX borehole has been drilled to the correct length. The head of the MPBX must be recessed in the hole 50mm (2") with grout/breather tube attached!

   To check the borehole length, run a length of grout tube into the intended borehole until it reaches the end of the borehole. Wrap a piece of electrical tape around the grout tube where it meets the collar of the borehole. Extract the tube, and compare the length to the MPBX length shown on the label on the MPBX head. The borehole should be long enough to accommodate the MPBX, with the instrumented head (nearest the lead-wire) recessed in the borehole 50mm (2") plus an additional 75 mm to 100 mm (3" to 4") for the grout/breather tube.

3. Boreholes must be free of water (common in down-holes) and debris (common in up-holes in fractured ground). For boreholes with water, an alternative to blowing out the water is toe-grouting with a low water content grout. This will push the water out of the borehole during the grouting process. If a borehole is not clean, the MPBX can get hung up or stuck while sliding it into place. If this happens the MPBX must be carefully extracted from the borehole and re-installed. It should be noted that while the MPBX is a very robust instrument it is still a passive device that is designed to pull apart and move with the ground. Efforts should be made to minimize the extraction force to less than 50 pounds.

4. Check the borehole diameter. The minimum diameter for an MPBX is 50mm (2").

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7 Unpacking/Uncoiling

Carefully lift the instruments out of the shipping crate, or, where instruments have been shipped individually, cut the plastic and bubble wrap off the outside of the MPBX's. Care should be taken when removing the bubble wrap, although most of the lead-wire is protected with white UV-HDPE, there is typically 5m (16') of unprotected lead-wire between the end of the white UV-HDPE and the connector.

Place the coiled MPBX on a flat surface in preparation for uncoiling. Ideally, this surface should be clean and dry to prevent mud from getting into the anchors, which affects the bond of the MPBX with the grout. If it is not possible to uncoil on a clean surface, then the MPBX anchors will need to be cleaned before the MPBX is inserted into the borehole. In areas where the drive or drift is very muddy, it may be prudent for the MPBX to be uncoiled and install from a scissor lift.

To uncoil the MPBX, perform the following steps:

1. Locate the coiled MPBX a distance that approximates the length of the uncoiled MPBX back from the intended borehole. Refer to the MPBX length information on the head label.

2. Cut the cable ties that hold the coiled lead-wire (white UV-HDPE tube) to the MPBX and lay the lead-wire off to the side where it won't interfere with the rest of the uncoiling process, or with any vehicular traffic. If the installation is being performed from the bed of a scissor truck, it is best to install the MPBX first, and then uncoil the lead-wire. This will help keep the deck of the scissor truck less cluttered.

3. Stand the coiled MPBX in a vertical position with the head close to the ground.

4. While one person holds the MPBX in the vertical position, have a second person cut the fibre tape that holds the MPBX together starting closest to the instrumented head. As each tape band is cut, the person holding the MPBX rolls it out along the floor of the drift until the next tape band is encountered, and it is cut in the same manner. Continue uncoiling until the MPBX is stretched out along the floor of the drift or excavation.

It is imperative that care be taken during the uncoiling process to ensure that damage to the MPBX, particularly the instrumented head, does not result. This is a two-person job.

Once the MPBX has been uncoiled, it is recommended that a reading be taken for all the anchor points. This will ensure that the MPBX is working properly before it is inserted into the borehole. Typical readings from a handheld readout unit should be between 50 and 100 (i.e. .5 and 1.0 Volts). If there are any problems with the MPBX at this point, contact MDT for further assistance.

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8 Re-coiling

If for any reason the MPBX needs to be re-coiled ensure that it is done so with a minimum diameter the same as when it was originally coiled. This is typically 1.5m (60”). Note that this is the minimum diameter, if space permits the MPBX should be coiled on as large of diameter as possible. Failure to do so could result in damage to the internal workings of the MPBX.

When coiling, the MPBX should be laid flat, and coiled vertically, rolling the instrument along its length, securing each new half-loop with fibre tape or cable tie. Rolling the MPBX ensures the anchor nodes stay in alignment. Excessive twist imposed along the length of the MPBX while coiling can cause binding.

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9 Installation

MPBX's are installed by permanently grouting them into a borehole. Take a moment to make sure that the MPBX is clean and free from mud or dirt. It is particularly important that the anchors are clean. If the anchors are packed with mud or dirt proper adhesion between anchor-grout-rock may not occur. Consequently, when the MPBX begins to stretch, the anchor can move in the hole, resulting in spurious data.

9.1 Safety Spring Hanger

Every MPBX is shipped with a safety spring hanger. The purpose of this hanger is to ensure the MPBX will not fall out of up-hole installations. **MPBX should never be installed without the hanger!** The spring hanger is a one-time use device and should only be installed once the borehole is verified to have been drilled to the correct length.

Locate the nut that is at the number 6 anchor node (the first anchor past the instrument head) and insert the spring hanger through the nut as shown in Figure 2 below such that the legs of the spring hanger are pointed towards the instrument head.

Figure 2 – Safety Spring Hanger

Once installed, the MPBX will be locked in place and removal will be very difficult, and as such it is not recommended without guidance from MDT. At this point, the instrument head can be wedged to prevent movement during grouting and grouting can commence as per Section 9.2.

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9.2 Grouting

There are two methods for grouting dependent on the machinery available. In both instances the goal is to ensure that the anchors are well coupled to the rock. When collar-grouting, grout is pumped starting at the collar and pushed from the instrumented head of the MPBX towards the toe. For toe-grouting, a grout tube is installed along the length of the MPBX and grout is forced from the toe of the borehole towards the collar.

9.2.1 Collar-Grouting

For collar-grouting, a breather tube needs to be attached along the length of the MPBX. The end of the breather tube should be cut at a 45 degree angle and taped such that 75mm to 100mm (3" to 4") of breather tube extends beyond the last anchor. The tape applied to the tip of the toe anchor should be of sufficient thickness and width to firmly affix the breather tube without covering the threaded portion of the anchor surface. The lower band of tape can be wider as this will be the last tape along the length of the MPBX. Refer to Figure 3 below.

Figure 3 – Breather Tube

The breather tube ensures that as the grout is being pumped in at the collar, the air can escape encapsulating 100 percent of the MPBX. Leave 2m to 4m (7' to 13') of extra breather tube beyond the head of the MPBX.

With the breather tube attached, slide the MPBX into the borehole until the MPBX head is 50mm (2") inside the collar of the borehole. With the head in this position, the lead-wire should come out of the hole at a low angle and be able to lie flat against the rock face. The MPBX head can be held in the borehole using wooden wedges and the supplied spring hanger. The wedges/spring prevent the MPBX from being pushed out of the borehole during grouting.

Insert a length of grout tube into the collar of the hole. Because the diameter of the MPBX head is 33mm (1.3"), there may be occasions where the head, grout tube and breather tube will not slide into the borehole to the required depth. To overcome this, flatten the grout tube slightly where it runs alongside the MPBX head (making it oval in shape). Do not over-flatten the grout

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tube as it can become weakened and rupture during the grouting phase. Under no circumstances should the breather tube be flattened.

In addition, burlap and/or expanding foam can be used to pack the collar. Once the collar is packed, and/or the foam has cured, the grouting can commence. A 0.42 to 0.46 water - cement (W:C) ratio grout is recommended for up holes to ensure full column grouting. For down holes, a 0.50 to 0.60 water - cement (W:C) ratio is suggested.

Put the excess breather tube in a bucket of water. Watch the bucket during grout pumping – bubbles should come from the end of the breather tube as the air is forced out of the hole. If there are no bubbles, the ground is likely very broken, and the air (and grout) is going off into the cracks in the rock.

Continue pumping until you can see the grout coming down the breather tube from the collar of the borehole. At this point, shut the grout pump off, cut the breather tube and kink it over to keep suction in the borehole, preventing air from traveling back up the breather tube and possibly allowing the grout to flow out of the borehole.

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9.2.2 Toe-Grouting

For toe-grouting, a grout tube needs to be attached to the toe of the MPBX. The end of the grout tube should be cut at a 45 degree angle and taped such that 75mm to 100mm (3" to 4") of grout tube extends beyond the last anchor. The tape applied to the tip of the toe anchor should be of sufficient thickness and width to firmly affix the grout tube without covering the threaded portion of the anchor surface. The lower band of tape can be wider as this will be the last tape along the length of the MPBX. Refer to Figure 4 below.

Figure 4 – Grout Tube

With the grout tube attached, slide the MPBX into the borehole until the MPBX head is 50mm (2") inside the collar of the borehole. With the head in this position, the lead-wire should come out of the hole at a low angle and be able to lie flat against the rock face. The MPBX head can be held in the borehole using wooden wedges and the supplied spring hanger. The wedges/spring prevent the MPBX from being pushed out of the borehole during grouting.

Avoid packing the collar so tight that air is not able to escape during toe grouting. When over packed, there is no place for the air to exit and the plug/wedges/MPBX can be pushed out of the borehole under the pressure of the grout column.

Because the diameter of the MPBX head is 33mm (1.3"), there may be occasions where the head and grout tube will not slide into the hole to the required depth. To overcome this, flatten the grout tube slightly where it runs alongside the MPBX head (making it oval in shape). Do not over-flatten the grout tube as it can become weakened and rupture during the grouting phase.

A 0.42 to 0.46 water - cement (W:C) ratio grout is recommended for up holes to ensure full column grouting. For down holes, a 0.50 to 0.60 water - cement (W:C) ratio is suggested. Begin pumping grout until the mixture begins to flow out of the collar of the hole. Shut off the grout pump. If the grout pump is so equipped, put it in reverse to create a negative pressure in the hole. This prevents the grout from continuing to flow out of the collar of the borehole.

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9.3 Securing the Lead-wire

The final step in the installation process is to secure the MPBX lead-wire to the back or wall of the excavation. The main objective here is to keep the cable tight to the back or wall so that it is out of the way, and cannot be damaged by a passing vehicle.

If there is screen in place, use cable ties to affix the lead-wire to the screen. Ideally the cable ties should be placed every 0.25m to 0.5m (0.75' to 1.75') when shotcrete is to be applied, and every 0.75m to 1.0m (2.5' to 3.3') when the lead-wire need only to be suspended out of the way. If screen is not being used, try to tie the lead-wire to existing ground support, or to services (air and water pipes, for example) that are nearby. ***Do not tie the lead-wire to, or in close proximity to, other AC or DC electrical conductors!!*** Doing so can introduce electrical "noise" into the instrument readings. Efforts should also be made to "skirt around" electrical substations and transformers.

If you are installing the MPBX's in an area where blasting is occurring (i.e. in a stope, or in a drift), it is strongly recommended that the lead-wire be shotcreted to the back or walls. It has been our experience that an active blast wave can tear the lead-wire from the back, thereby affecting the functionality of the MPBX. While the white UV-HDPE covering does provide some protection, it will not protect from these types of damage. If the lead-wire is to be shotcreted, it should be attached to the back or walls along a bolt line, where any shearing action along the rock will be minimized. This will help to minimize damage to the lead-wire due to movement of the rock itself.

Shotcrete the lead-wire in the usual manner using non-fibrous shotcrete, making sure that there are no voids behind the lead-wire, and that the lead-wire is covered 0.75m (2.5') on either side of the wire line to a minimum depth of 50mm (2").

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9.4 Initial Instrument Reading

There are four sets of readings which must be taken during the installation of an MPBX.

The first set of readings should be performed upon arrival of the MPBX while still coiled (the "Coiled Readings"). This is to ensure that the MPBX has not been damaged during shipping.

The second set of readings should be performed after the MPBX has been uncoiled (the "Uncoiled or Straight Readings"), either on the scissor truck, the floor of the work area, or up the borehole (prior to grouting) to ensure the MPBX is still functioning as expected.

The third set of reading should be performed immediately after grouting (the "Post-Grout").

Lastly, the final set of readings should be performed no sooner than 24 hours after grouting (the "Initial Readings"). These four sets of readings should be retained and recorded for each MPBX as they can be used to help with diagnosing instrument problems should they arise.

The readings taken after 24 hours of grout cure will be used as baseline readings for all the subsequent calculations. Note that in some cases, curing of the grout can put strain on the MPBX. If the baseline reading is taken before the grout has fully cured, the resulting strains may appear bizarre, and won't reflect the actual changes in the ground conditions.

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9.5 Illustrated Example Installation

The following images provide a brief overview of an installed MPBX.

Figure 5 – Drilled Borehole

Figure 6 – Uncoiling and Adding Grout Tube

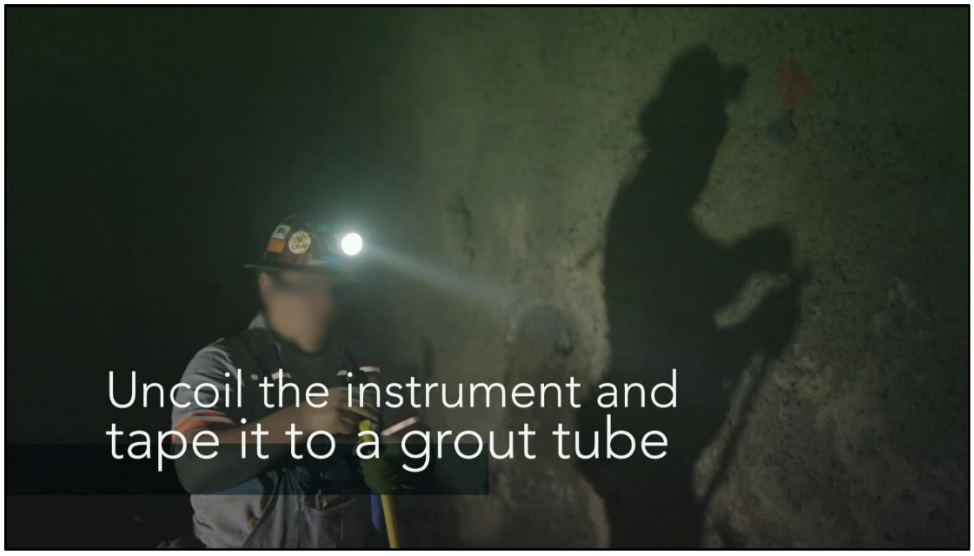

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Figure 7 – Inserting MPBX into the Borehole

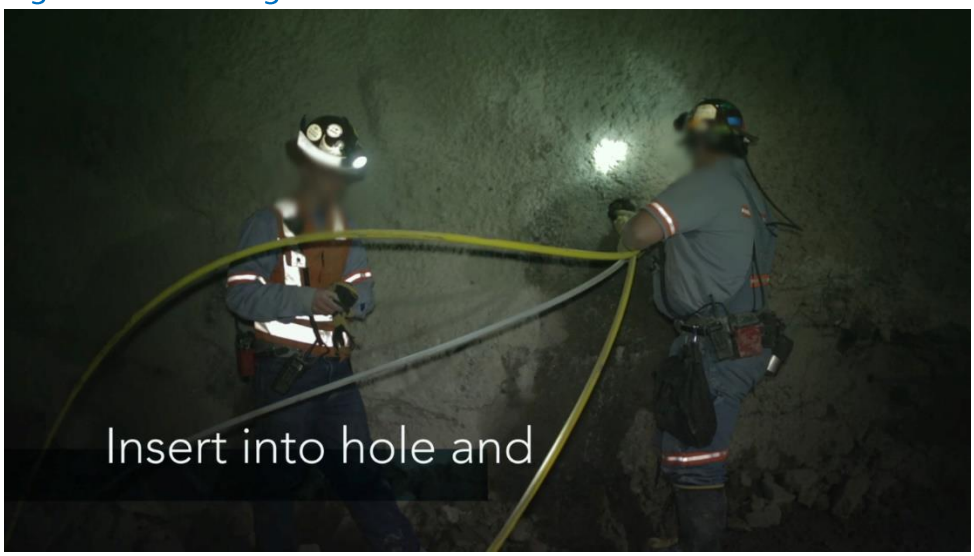

Figure 8 – Grouting MPBX

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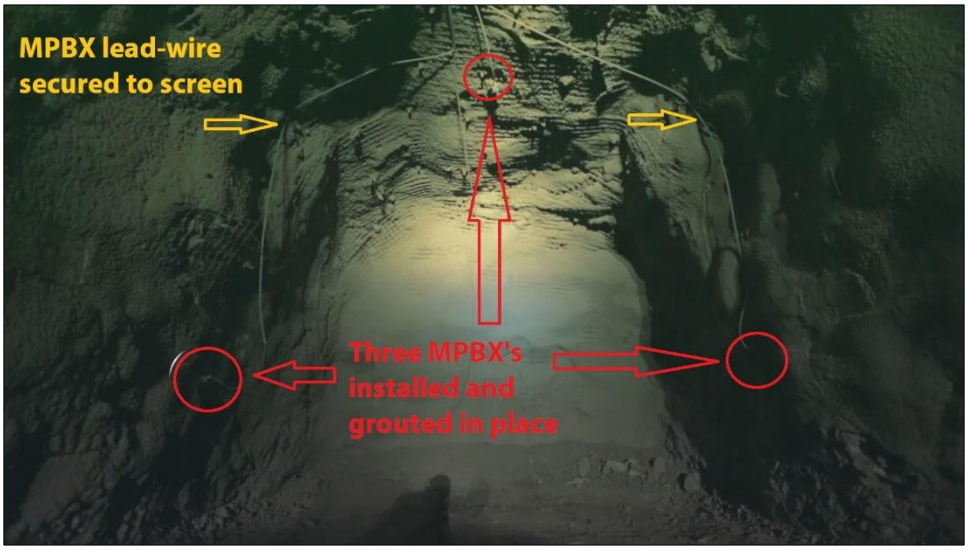
Figure 9 – Installed MPBX



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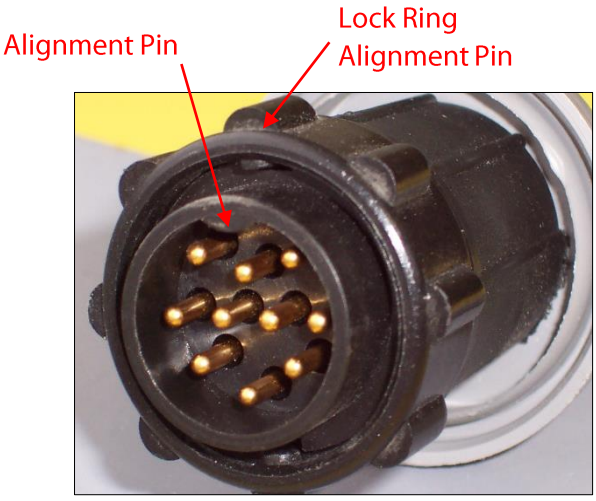
10 How to mate the MPBX connectors

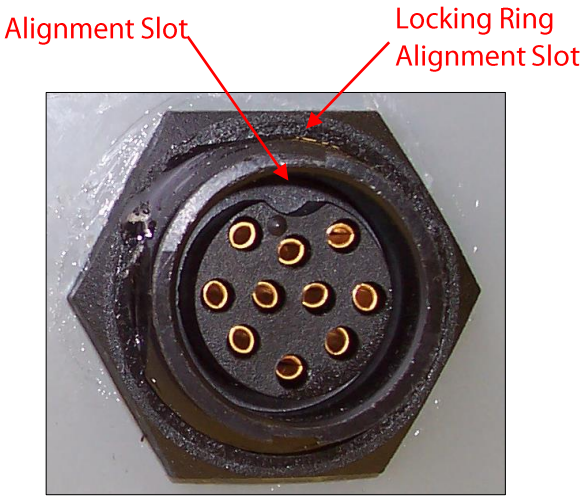
All MDT SMART device (instruments, loggers and readout boxes) connectors mate by first aligning the alignment pins and are then locked in place with a locking ring.

To ensure proper fit and connection please follow these directions.

Rotate the male connector until the alignment pin of the male connector is aligned with the alignment slot on the female connector. A slight wiggle will engage the gold colored contacts. After coupling the two half's together, with light pressure, rotate the locking ring on the male connector until the locking ring engages the female connector. When properly engaged the locking ring will move towards the female connector approximately 1/16". Still applying light pressure continue to rotate the locking ring a half-turn clockwise to lock the connector in position. Note the locking ring on the male connector is not threaded and is not intended to engage the threads on the female connector.



Male connector on MDT SMART instruments.



Female connector on back of SMART Log and SMART Reader.

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11 Pinout & Colour Codes

11.1 SMART Instrument 10-Pin Connector (MPBX, Cable, Cable-SP)

Each SMART Connector Repair Kit comes complete with a 10-pin male connector. The associated channel and wiring colour code is depicted in the figures below. The colour code is viewed looking at the mating side (front) of the connector.

Figure 10 – 10-Pin Male (Legacy)

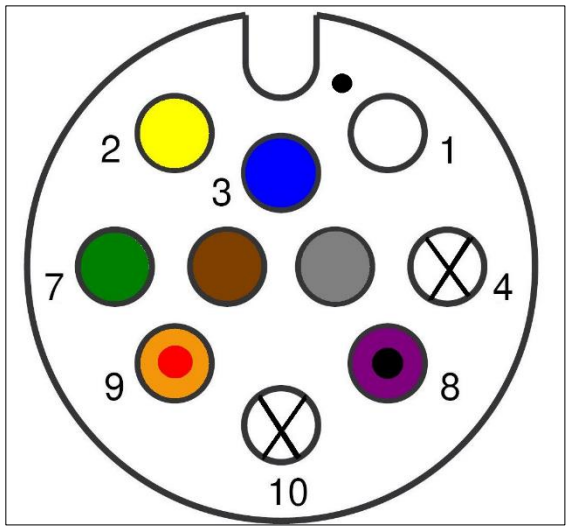


Figure 12 – 10-Pin Male (w Digital ID)

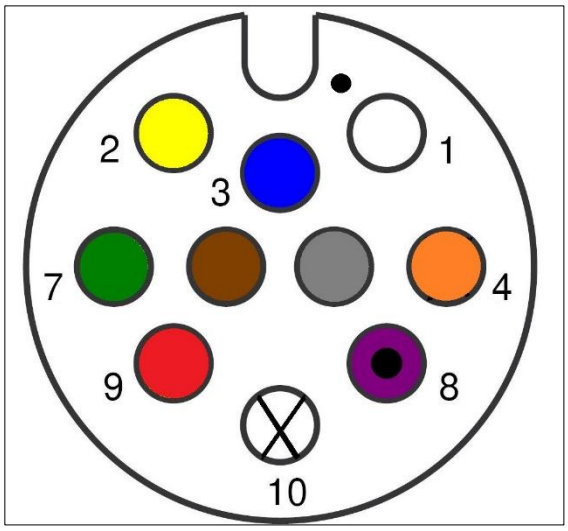


Figure 11 – 10-Pin Female (Legacy)

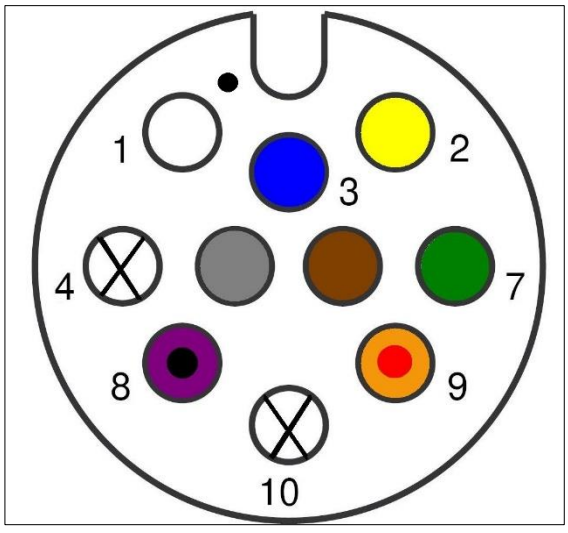
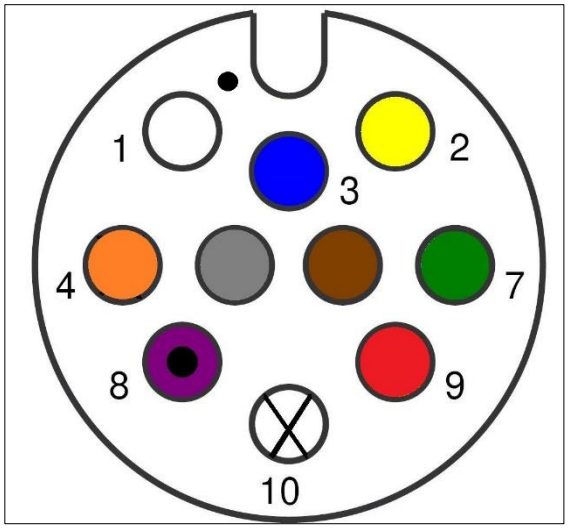


Figure 13 – 10-Pin Female (w Digital ID)



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12 Specifications

Table 3 – Connector Pinout

	Without SMART ID		With SMART ID	
Pin	Colour	Function:	Colour	Function:
1	White	Anchor 3	White	Anchor 3
2	Yellow	Anchor 2	Yellow	Anchor 2
3	Blue	Anchor 1	Blue	Anchor 1
4		No Connection	Orange	SMART ID data
5	Gray	Anchor 6	Gray	Anchor 6
6	Brown	Anchor 5	Brown	Anchor 5
7	Green	Anchor 4	Green	Anchor 4
8	Black & Purple	Ground	Black & Purple	Ground
9	Red & Orange	Positive Supply	Red	Positive Supply
10		No Connection		No Connection

Table 4 – Electrical Specifications

Electrical Specifications:	
Electrical Stroke Lengths	31.75, 63.5, 127, 190.5, 254, 508 mm
Resistance Values	30 kΩ/channel, 5 kΩ between Pins 8 and 9
Resistance Tolerance	±10%
Linearity Tolerance	±1.0%
Resolution	Essentially infinite (<0.01 mm)
Maximum Operating Voltage	28 V
Output Smoothness	<0.1% against input voltage
Power	1.2 W
Maximum Wiper Current	1 mA

Table 5 – Mechanical Specifications

Mechanical Specifications:	
Mechanical Stroke	31.75, 63.5, 127, 190.5, 254, 508 mm
Displacement Speed	< 20 mm/s

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Table 6 – Environmental Specifications

Environmental Specifications:	
Operating Temperature	-20 Celsius to +80 Celsius
Operating Pressure	80 kPa to 110 kPa
Air with Nominal Oxygen content	Typically 21 % v/v

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13 Parting Thoughts

While this set of instructions will handle most cases, situations it does not cover will inevitably arise. In these cases, contact MDT. Our staff has been involved with many installations, and can help you to find a solution to your particular case. Questions can be directed to support@mdt.ca or 1-613-549-5223.

14 Warranty

Mine Design Technologies Inc. (MDT) warrants its MPBX product line (herein referred to as the Product(s)) against defects in materials and workmanship for a period of ONE YEAR from the date of purchase. While MDT strives to produce a superior quality products in every respect; the Products are intended for use in extreme environments under conditions of continued stress where in the instrument can be damaged and/or destroyed as a result of actions beyond MDT's control. As such unless it can be shown unequivocally that the Product was defective at the time of installation, the warranty on the Product(s) is null and void should the instrument fail after installation. Except for obligations specifically assumed by MDT under warranty, MDT will not be liable for any loss, damage, cost of repairs, incidental or consequential damages of any kind whether or not based upon expressed or implied warranty, contract, negligence or strict liability arising in connection with the design manufacture, sale, use or repair of the Product(s). This expressed limited warranty is extended by MDT to the original end purchaser only and is not assignable or transferable to any other party. This is the complete warranty for the Product(s). MDT assumes no obligations or liabilities for any additions to this warranty unless made in writing and signed by an officer of MDT. Unless made in a separate agreement between MDT and the original end user purchaser, MDT does not warrant the installation, maintenance or service of this Product.

THE WARRANTY DOES NOT COVER:

a) Defects or damage resulting from use of the Product in other than its normal and customary manner.
b) Defects or damage from misuse, accident, or neglect.
c) Defects from improper testing, operation, maintenance, installation, alteration, modification or adjustment.
d) Product disassembled or repaired in such a manner as to adversely affect performance or prevent adequate inspection and testing to verify any warranty claim.
e) Any instrument that cannot be accessed to verify any warranty claim.
f) All freight costs to the MDT repair depot.

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