LWRS Deliverable M3LW16OR040363

Alkali-Silica Reaction Test Assembly – Report describing the procurement of materials and equipment for the ASR test assembly

Identification of Mechanisms to Study Alkali-Silica Reaction Effects on Stressed-Confined Concrete Nuclear Thick Structures

Prepared by:

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January 15 2016

Introduction

The first report related to this project, has been delivered November 30 2015. It has detailed the design of a first version of a comprehensive instrumentation plan including different types of sensors and data acquisition systems.

The current document will present the details of all the selected materials and equipment required for the progress of this project. It will include the following parts:

- Instrumentation (update);
- Concrete specimens;
- Environmental chamber;
- Steel frame;
- Post-tensioning system.

Instrumentation

The instrumentation was updated according to feedback and subsequent analysis. The final instrumentation plan can be found in Appendix 1. The following paragraphs indicate the current status regarding the selection and the procurement of the sensors and the data acquisition systems.

A- Data Acquisition (DAQ) systems

The research team (RT) has identified four different types of Data Acquisition systems (DAQ). Two of them need to be purchased and the two remaining will be borrowed. They will be installed inside the environmental chamber (will be described further) throughout the project. To protect them from the harsh environmental chamber conditions and any other source of damage, the DAQs will be installed inside specifically purchased enclosures.

NI DAQ: The National Instruments (NI) DAQ system will collect data for some of the sensors we plan to use in this project: KM100B, KM100BT, TPC, and Vishay quarter-bridge strain gauges (refer to Appendix 1 for legend and implementation). The acquisition of the NI DAQ is currently in progress. Its use requires the development of specific software, as well. The RT is currently discussing this aspect with Prince Consulting, LLC. The final quote for the NI DAQ system (without the software) can be found in Appendix 2.

SOFO VII reading unit: This universal reading unit is able to measure both SOFO (Interferometric) and MuST FBG (Fiber Bragg Grating) sensors. Refer to Appendix 3 for the related quote.

LUNA: ORNL has recently acquired a Luna's Optical Distributed Sensor Interrogator. This system will be used throughout the project.

Acoustic Emission data analysis: The University of South Carolina, represented by Dr Paul Ziehl in this project, will provide the RT with their 16-channel Acoustic Emission data acquisition system throughout the project.

B- Sensing tools:

All the sensors and DAQs will be calibrated and tested before implementing the sensors in the specimens.

KM sensors: The total number of KM strain transducers has been quoted and is ready for purchasing. Refer to Appendix 4 for quote and supplier details.

Total Pressure Cells (TPC): The NI DAQ is able to collect data from the TPCs, in the case the electrical output TPC were used instead of the vibrating wire ones. For this reason, we have made the decision to opt for the first type. Refer to Appendix 5 for quote and supplier details.

Strain gauges: The total number of standard electrical strain gauges, required for the instrumentation of the rebar within the specimens, is available. No purchasing is necessary.

Probex: The cost of the Probex system may be too high to warrant its continuous use in this project. Further discussion needs to be made about the rental option and the monitoring frequency. Refer to Appendix 6 for rental cost and supplier details.

SOFO: The SOFO long gauges are selected to monitor surface deformation and are supposed to be implemented at the bottom of each specimen. Refer to Appendix 7 for quote and supplier details. They require a specific DAQ system.

OF: The distributed optic fiber instrumentation plan has been finalized. The purchasing of fiber optic is to be coordinated with ORNL.

AE sensors: The purchase of these sensors is to be coordinated with ORNL and the University of South Carolina. Refer to Appendix 8 for quote and supplier details.

Concrete Specimens

Three concrete specimens are going to be cast and equipped with different types of sensors in order to continuously monitor strains, stresses, and temperature changes on their surface and in the bulk. They will be 11’-4” by 9’-8” by 40” in thickness.
The University of Alabama, represented by Dr Eric Giannini in this project, is performing a series of laboratory tests to determine the appropriate types of aggregates and the concrete formulation.

At the same time, the RT is in the process of investigating a ready mix supplier that is close to the University of Tennessee, and willing to produce and deliver a concrete including reactive aggregates.

The two first specimens will be created using highly reactive silica aggregates. The first one will be cast into a highly rigid steel frame, and occasionally submitted to post tension efforts. Hence, it is referred to as the "confined specimen."
Displacement in two directions will be controlled using a plate girder system in combination with post-tensioned tendons.

In the second specimen, the expansion will not be constrained. This specimen will be acting as a "control specimen" whereby a comparison of the shear properties between a restrained ASR growth (1-dimensional) and unrestrained ASR growth (3-dimensional) can be made.
The third specimen will be cast using nonreactive aggregate and will be used as a "general control specimen."
The ASR being endothermic, the formation of the silica gel can be accelerated, by maintaining the specimen at a temperature of approximately 38^{o} C (100^{o} F). Also for the reaction to occur, excess moisture must exist in the free pore space of the concrete specimen (at least RH 95%).
Consequently, the three specimens will be subjected to the same, permanently controlled and maintained temperature and moisture exposure in the environmental chamber, described below.

Environmental Chamber

Due to the size of the specimens, this chamber is anticipated to be about 24 feet by 52.5 feet in dimension. So far, the RT is leaning towards a prefabricated modular structure that will be assembled at the University of Tennessee, within the High-bay Structural laboratory, as shown in Figure 1.

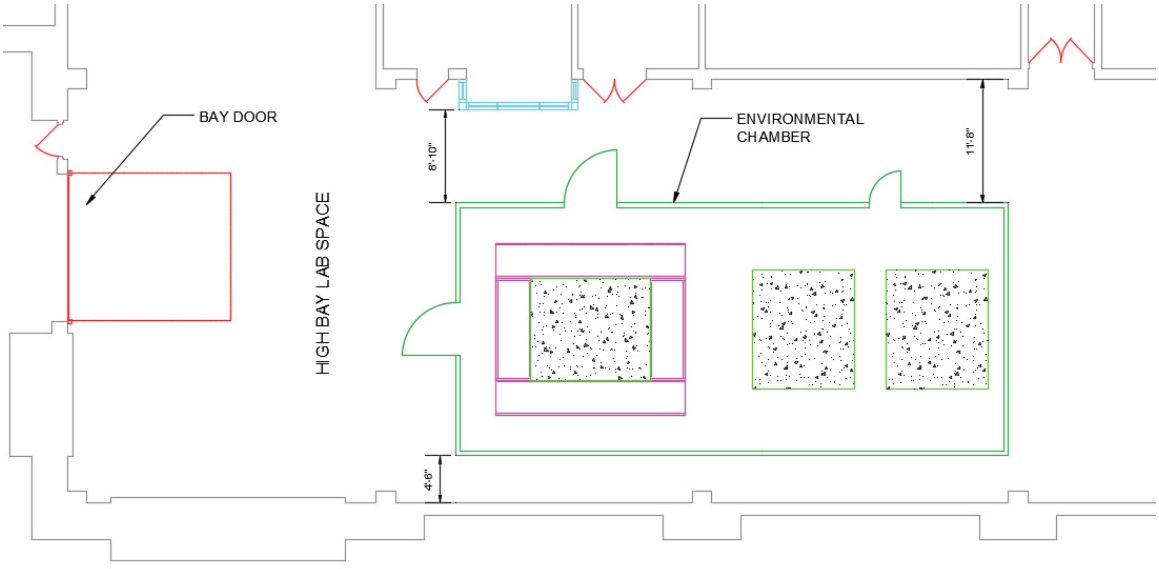


Figure 1. Placement of chamber within high-bay lab

According to the site constraints, that we are in the process of identifying and addressing, the construction could be performed either, totally after the concrete pouring, or in two phases: One phase before concrete pouring, and the second one afterwards.
The chamber will basically consist of three parts: 1) walls, 2) roof, and 3) electrical and other equipment located on the roof.

The "confined specimen" will be placed at the extremity of the chamber. Two 5-foot doors will be placed at each side of this specimen to allow access for re-tensioning of the post-tension tendons when needed. The other two specimens do not require restraining devices. One additional three-foot door is to be constructed opposite these specimens. This should provide enough access to allow measuring and maintenance of the specimens and equipment.

The RT has had many meetings with UTK Facilities Services, during the two last months. The aim was to ensure that the structure design will comply with all the safety requirements and that the construction will be completed on time and on budget.
The UTK Facilities Services have contacted the engineering team of *Nor-lake Scientific* to investigate viable technical options and request a preliminary quote as well.
Nor-lake Scientific is recognized for its high-quality industrial modular constructions, among others. Refer to Appendix 9 for the provided preliminary quote.

The next step was to send a performance requirement to UTK Facilities Services. After making sure that it covers all the different aspects, they will send it to, at least, three bidders including *Nor-lake Scientific.*

Below is the anticipated schedule for the completion of the environmental chamber:

State Architect Approval- January 8th

- Develop and Review Specification (1 week) – January 15th
- Bid through Purchasing (3 weeks)- January 18-February 8th
- Award (2 weeks)- February 22nd
- Submittals (3 weeks)- March 14th
- Fabrication (8 weeks)- May 9th
- Shipping (1 week) – May 16th
- Installation (3 weeks)- June 6th

Steel Frame

This section of the report deals with the design of the steel frame and connection details. The design, presented below, is the ideal option in terms of reducing deflections.

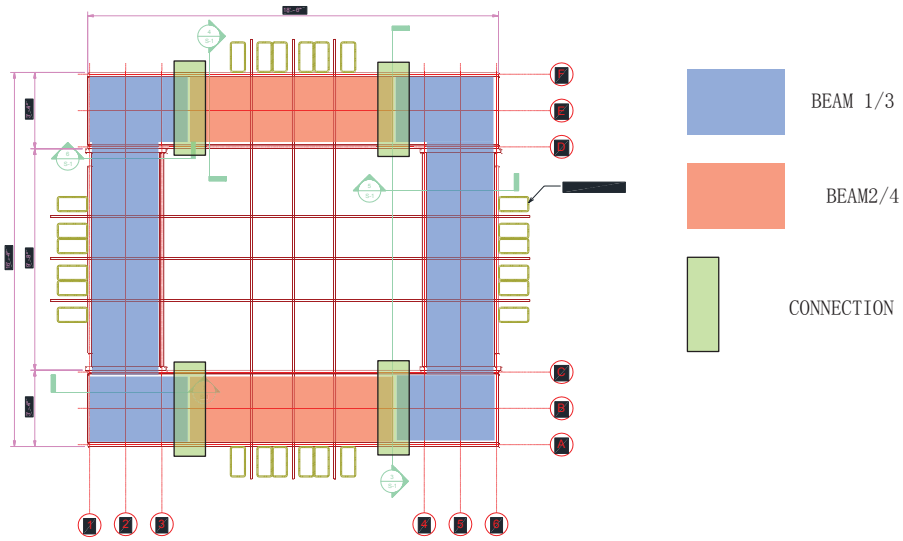


Figure 2. Design of steel confinement frame.

As shown in Figure 3, the cross section of the steel frame is adjusted in order to create a higher moment of inertia. Besides, the web thickness is determined to prevent web buckling. To reduce expected deflections, the current flange thickness might be reexamined. A total of three webs are likely needed in order to control local deflections due to the internal acting pressure of the concrete expansion. Currently, The RT is conducting a full-scale investigation on the steel frame. The most efficient design will be selected and fully designed before submitting specifications and drawings to bid.

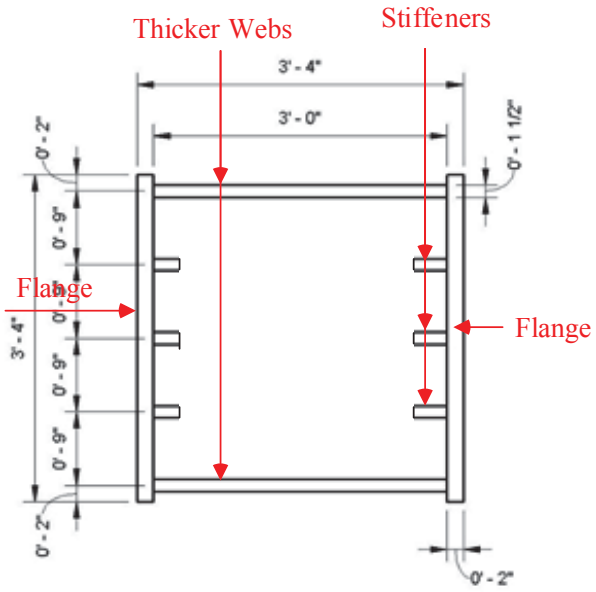


Figure 3. Cross section of the proposed steel confinement

The connection detail and the cross-section are being designed. A complete set of Documents including drawings will be completed by January 31. The finale drawings

will be sent to steel suppliers to provide accurate estimates. Besides, specifications will be completed to put the steel confinement frame out to bid.
According to a discussion with a steel supplier, we are expecting the total fabrication of the frame to be around $200,000.
The entire month of February is available for the submissions and selection of bids. After acceptance of a bid, fabrication of the steel frame is anticipated to begin in March, and with the previous estimate of 8 to 10 weeks, the steel frame will be built and delivered by beginning to mid May 2016.

Post-Tension

DSI America was contacted for consulting on the post-tension system. DSI suggested the use of a 2.5" Gr. 150 thread bar system with bearing plates and nuts shown in Figure 4. All components were suggested to be galvanized in order to prevent against corrosion in the humid environment. The hydraulic jack to be used with the thread bars is small enough to be lifted by a single person within the environmental chamber. This would allow the stressing of the bars to be completed in a relatively short amount of time. Each 2.5" Thread bar has a maximum capacity of 546 kips (2409 kN), which should effectively correct any deformations that possibly occur. The post-tensioning will only be used as needed in order to correct the experienced deflection of the steel frame.

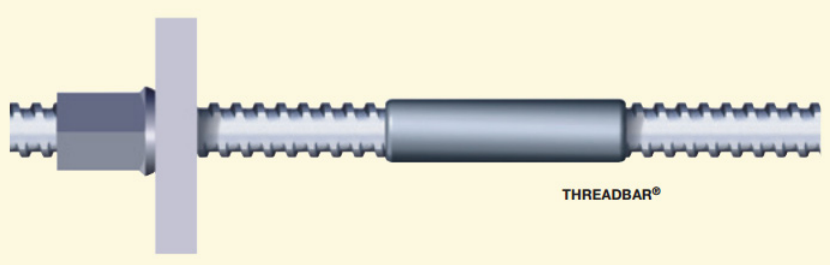


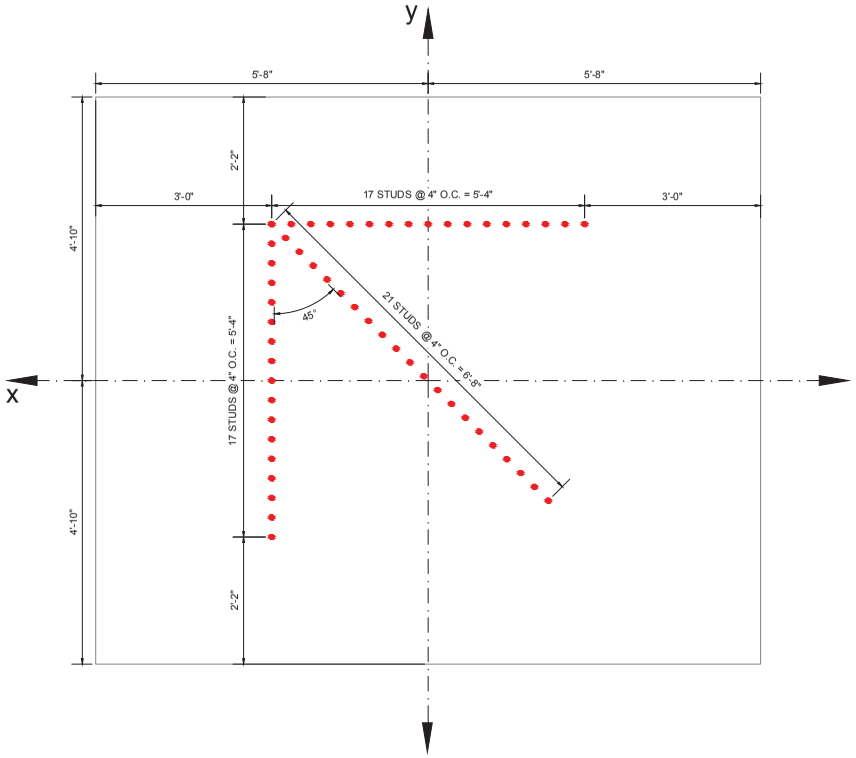
Figure 4. Thread bar post-tension

The stressing of the bars would have to be staggered in order to avoid eccentric loading. That is, one bar would be stressed to 25% capacity, and then the next bar would be stressed to 25%. This process would be continued in 25% intervals until stress capacity is achieved in all thread bars.

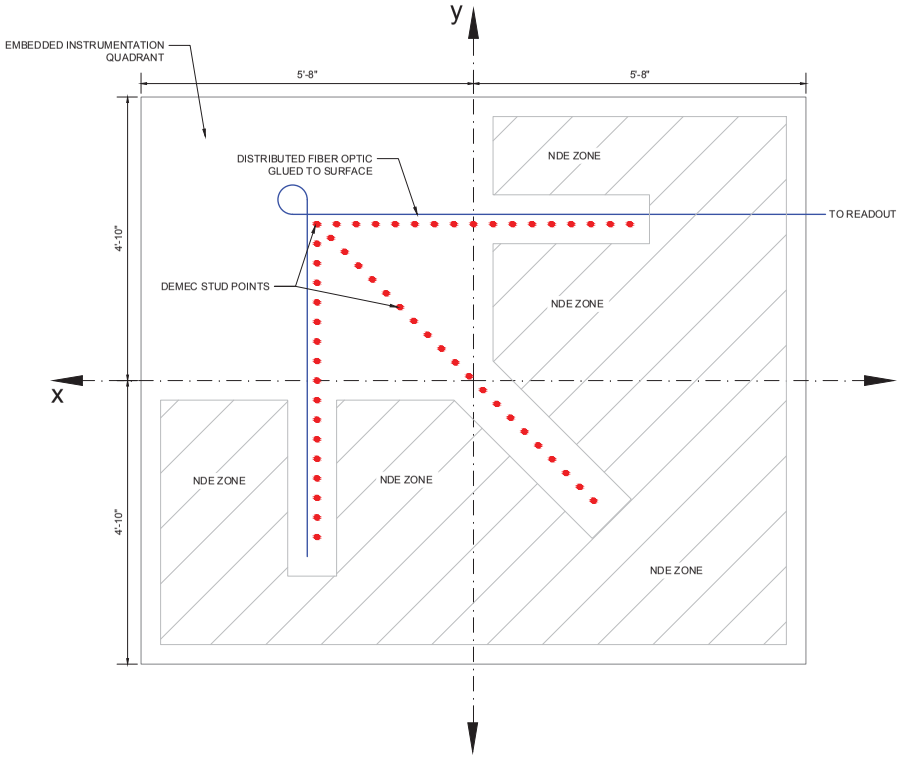
However, for the first stressing of the bars, the maximum capacity may not be needed. The thread bars will be re-tensioned as needed over the course of the expansion period.

Previous quotations from DSI list the price of four thread bars and accessories at approximately $5,000. The hydraulic jack can be rented for a minimum of a month. The monthly rental of the 2.5" thread bar jack was previously quoted at $1,250. An updated quote has been requested.

A thorough and detailed explanation of the Thread bar system can be found on Page 22 of Appendix 10.



2 / T1.1 TOP SURFACE STRAIN INSTRUMENTATION LAYOUT
SCALE: 1" = 1'-0"



1 / T1.1 TOP SURFACE STRAIN INSTRUMENTATION LAYOUT
SCALE: 1" = 1'-0"

NOTES:
- TOP SURFACE INSTRUMENTATION WILL BE THE SAME FOR ALL CONCRETE SPECIMENS.
- A GILSON HM-240 ADJUSTABLE READER WILL BE USED TO MEASURE THE DISPLACEMENT BETWEEN DEMEC STUDPOINTS.

DESIGNED BY:
DRAWN BY: NWH
CHECKED BY:

ASR RESEARCH

TOP SURFACE STRAIN INSTRUMENTATION

UNIVERSITY OF TENNESSEE KNOXVILLE
CIVIL AND ENV. ENGINEERING
851 NEYLAND DR.
KNOXVILLE, TN 37996-2313

REVISIONS

DATE	DESCRIPTION

FILE NO. 0000

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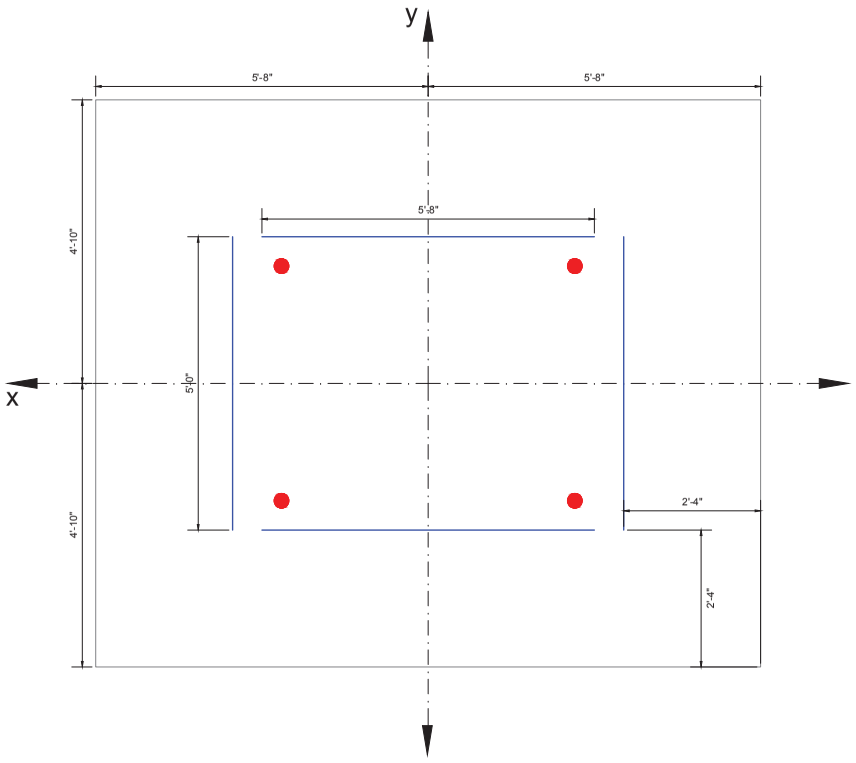
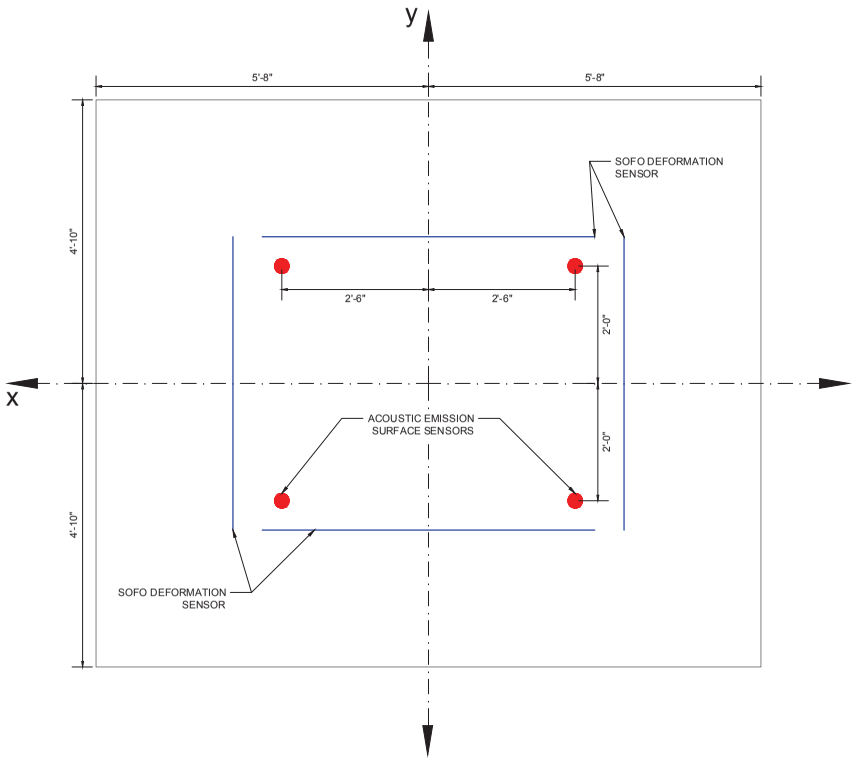
T1.1



2 T1.2 BOTTOM SURFACE STRAIN INSTRUMENTATION - DIMENSIONED LAYOUT

SCALE: 1" = 1'-0"



1 T1.2 BOTTOM SURFACE STRAIN INSTRUMENTATION - GENERAL LAYOUT

SCALE: 1" = 1'-0"

DESIGNED BY:

DRAWN BY: NWH

CHECKED BY:

ASR RESEARCH

BOTTOM SURFACE STRAIN INSTRUMENTATION

UNIVERSITY OF TENNESSEE KNOXVILLE

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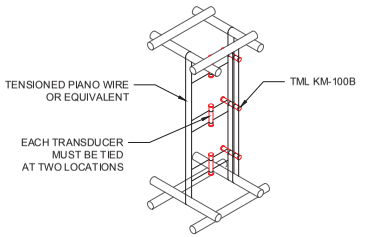
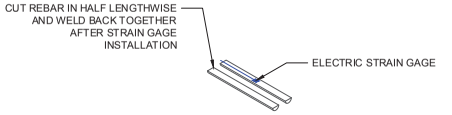
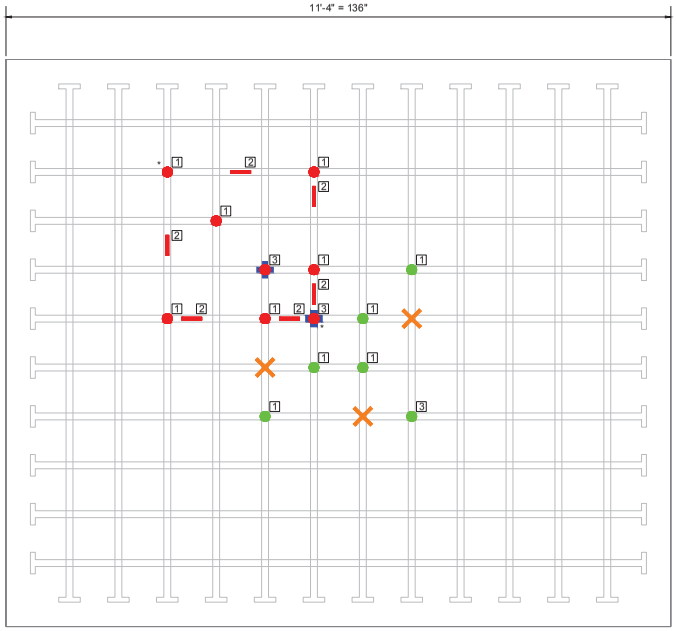
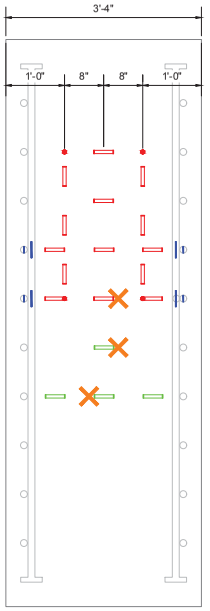


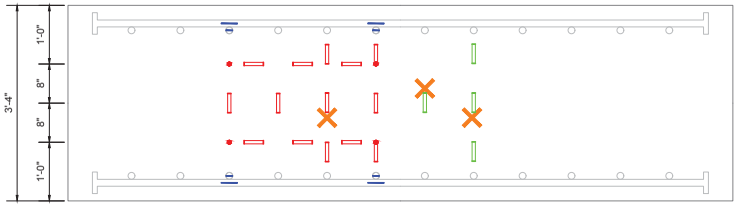
3 / T1.3 ILLUSTRATION OF HANGING EMBEDDED STRAIN GAGES
SCALE: 1" = 1'-0"

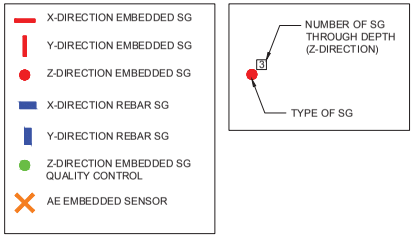


4 / T1.3 ILLUSTRATION OF ATTACHING ELECTRIC STRAIN GAGES
SCALE: 1" = 1'-0"









1 / T1.3 EMBEDDED STRAIN GAUGE LAYOUTS FOR SPECIMENS 1 AND 2
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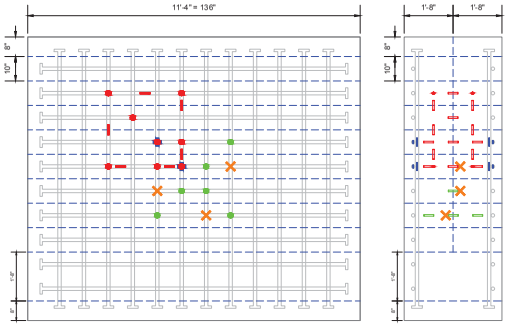

4 / T1.3 PROPOSED CUTTING LINES FOR MECHANICAL TESTING
SCALE: 1/2" = 1'-0"

NOTES;
- "REBAR SG" ARE TO BE STRAIN GAGES APPROPRIATELY ATTACHED TO REINFORCING BARS BY CUTTING REBAR ALONG CENTER AND THEN WELDING BACK TOGETHER AFTER SG INSTALLATION

EMBEDDED INSTRUMENTATION QUANTITIES

SPECIMEN	SENSOR	QUANTITY
1	KM-100B	28
	KM-100BT	4
	ELECTRICAL STRAIN GAUGE	8
2	KM-100B	28
	KM-100BT	4
	ELECTRICAL STRAIN GAUGE	8
3	KM-100B	8
	KM-100BT	4
	ELECTRICAL STRAIN GAUGE	8

DESIGNED BY:
DRAWN BY: NWH
CHECKED BY:

ASR RESEARCH

EMBEDDED STRAIN INSTRUMENTATION

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T1.3

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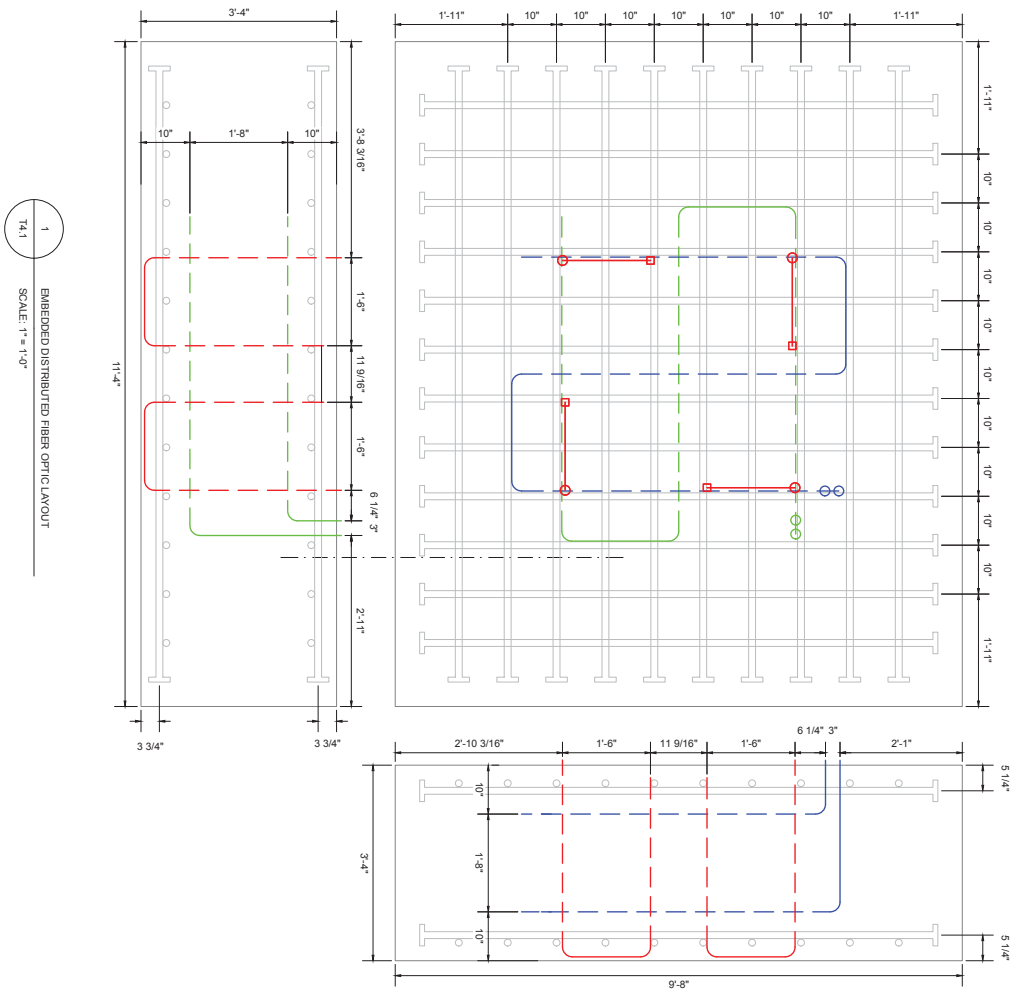
DRAWN BY: NWH	STRESS MEASURING INSTRUMENTATION			DRAWING NO. 0000	
CHECKED BY:					

STRESS INSTRUMENTATION - PLAN LAYOUT
SCALE: 1" = 1'-0"
1
T2.1

STRESS INSTRUMENTATION - ELEVATION LAYOUT
SCALE: 1" = 1'-0"
4
T1.1



1 / T4.1

EMBEDDED DISTRIBUTED FIBER OPTIC LAYOUT

SCALE: 1" = 1'-0"

T3.1	
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CIVIL AND ENV. ENGINEERING
851 NEYLAND DR. KNOXVILLE, TN 37996-2313

ASR RESEARCH

EMBEDDED DISTRIBUTED FIBER OPTIC

DESIGNED BY:

DRAWN BY: NWH

CHECKED BY:

Quotation No.: 2238633

Sihem Le Pape
University of Tennessee - Knoxville
1408 Circle Dr
KNOXVILLE, TN 37996
UNITED STATES

Quotation Date: 18-DEC-2015
Quote Valid Until: 14-JAN-2016
Phone:
Fax:
Contact No: 8546453

Quotation No. 2238633

Please indicate the above quote number when ordering for faster processing. Contact us at (800) 433-3488, or submit orders to orders@ni.com.

Line No.	Part Number	Description	Qty.	Unit Price	Discount	Amount
		NI CRIO SYSTEM Configuration ID: CR4830808 				
1.1	781093-01	NI PS-15 Power Supply, 24 VDC, 5 A, 100-120/200-240 VAC Input Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: China* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	1	~~221.00~~ 198.90	10.00%	198.90
1.2	779001-01	NI 9211 4-Ch ±80 mV, 14 S/s, 24-Bit Thermocouple Differential Analog Input Module Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Hungary* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	3	~~362.00~~ 325.80	10.00%	977.40
1.3	779521-01	NI 9237 4-Ch 50 kS/s per Channel, 24-Bit Bridge Analog Input Module Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Hungary* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	16	~~1,349.00~~ 1,011.75	25.00%	16,188.00
1.4	779781-01	NI 9219 4 Ch-Ch Isolated, 24-bit, ±60V,100S/s Universal AI Module Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Hungary* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	1	~~1,098.00~~ 988.20	10.00%	988.20

Quotation No.: 2238633

Line No.	Part Number	Description	Qty.	Unit Price	Discount	Amount
1.5	779994-01	NI 9236 350ohm, 8-Ch, 24-Bit, 2.5Vex, 10kS/s, 1/4 Bridge Input Module Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Hungary* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	3	~~1,648.00~~ 1,483.20	10.00%	4,449.60
1.6	SRV-CR4830808	Standard Service Program for CompactRIO Systems (3 years) Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Hungary* Note: Service applied to eligible items. See Service Details for more information.				2,901.40
1.7	782663-01	cRIO-9068 8-Slot Integrated Controller and Chassis System, Artix-7 FPGA Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Hungary* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	1	~~3,999.00~~ 3,599.10	10.00%	3,599.10
1.8	783376-01	NI 9149 8 Slot Ethernet Expansion chassis for C Series Modules Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Malaysia* Service details for this product: NI Standard Service Program for Systems Duration: 3 Year(s) 15% multiyear discount applied.	3	~~999.00~~ 899.10	10.00%	2,697.30
1.9	779017-01	NI 9932 Strain relief & high voltage conn kit, 10-pos screw terminal plug w/ cable housing for 10-pos. screw terminal Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Germany*	3	~~31.00~~ 27.90	10.00%	83.70
1.10	196720-01	NI 9972 Strain relief kit for 6-pos spring terminal connector (qty 4) Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Germany*	1	~~31.00~~ 27.90	10.00%	27.90
1.11	196809-01	NI 9949 RJ-50 (female) to Screw Terminal Adaptor (Qty 4) Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: China*	19	~~192.00~~ 144.00	25.00%	2,736.00

Quotation No.: 2238633

Line No.	Part Number	Description	Qty.	Unit Price	Discount	Amount
1.12	780216-01	NI 9965, Backshell for 24 Pos Spring Terminal (QTY 1) Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: Germany*	3	~~31.00~~ 27.90	10.00%	83.70
1.13	182219-01	Type E1 Twisted-pair (10Base-T) Cable for GPIB-ENET, 1M Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: China*	1	~~17.00~~ 15.30	10.00%	15.30
1.14	194612-02	RJ50 Cable for 9944, 9945, and 9949, 2m (qty 4) Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: China*	19	~~31.00~~ 23.25	25.00%	441.75
1.15	779018-01	NI 9915 DIN Rail Mounting Kit for 8-slot cRIO/cDAQ Chassis Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: USA*	1	~~31.00~~ 27.90	10.00%	27.90
1.16	779454-01	NI 9917 Industrial Enclosure, solid door, with internal panel for mounting Standard Delivery time: 12 - 20 business days ARO. *Country of Origin: USA*	4	~~309.00~~ 278.10	10.00%	1,112.40
2	960680-001	Traceable Calibration Option for NI Service Program for Hardware - Includes coverage for traceable calibration service only Contact Customer Service for Availability SN: 126B415 Duration: 1 Year(s) Service Dates: 18-DEC-2015 - 17-DEC-2016	1	186.00		186.00
3	960680-001	Traceable Calibration Option for NI Service Program for Hardware - Includes coverage for traceable calibration service only Contact Customer Service for Availability SN: 126B428 Duration: 1 Year(s) Service Dates: 18-DEC-2015 - 17-DEC-2016	1	186.00		186.00
4	960680-001	Traceable Calibration Option for NI Service Program for Hardware - Includes coverage for traceable calibration service only Contact Customer Service for Availability SN: 12605DA Duration: 1 Year(s) Service Dates: 18-DEC-2015 - 17-DEC-2016	1	186.00		186.00

Sub-Total:	**$ 45,638.35**	**18.74%**	**$ 37,086.55**
Shipping and Handling:			**$ 166.27**
Total:			**$ 37,252.82**

Currency quoted in: U. S. Dollars

To ensure the highest quality service in order processing and support after delivery, please provide end-user information with your purchase order.

Additional Information:

- Payment Terms: Net 30
- Freight Terms: NI Weight Based Shipping

Country of origin is subject to change. Actual country of origin is provided on the commercial invoice, pack slip and product label.

Unless expressly indicated by NI herein, all sales are subject to the enclosed National Instruments terms and conditions of quotation and sale. National Instruments shall not be bound by any conflicting or additional Terms and Conditions. Standard shipping dates are based on product availability at time of quotation and are subject to change without notice. Not all products produced by National Instruments are made in the U.S.A.

Yours sincerely,
National Instruments

Martin Garcia

NATIONAL INSTRUMENTS
TERMS AND CONDITIONS OF SALE

The terms and conditions detailed herein ("Agreement") apply to your ("Customer") purchase from NI of NI hardware ("Hardware"), licenses to use NI software ("Software"), and Non-NI Branded Products (collectively the "Product(s)"), as well as NI hardware and software services and support ("Services"). NI means the National Instruments affiliate identified on the Quote, order acknowledgement, or invoice, or in the absence of an identified National Instruments affiliate, then National Instruments Corporation. THIS AGREEMENT SHALL APPLY UNLESS CUSTOMER AND NI HAVE ENTERED INTO A SEPARATE SIGNED AGREEMENT APPLICABLE TO THE PURCHASE OF THE PRODUCTS OR SERVICES. By placing an order with NI, Customer agrees to be bound by the terms of this Agreement. NI EXPRESSLY OBJECTS TO AND REJECTS ANY TERMS AND CONDITIONS IN CUSTOMER'S PURCHASE ORDER OR OTHER SIMILAR DOCUMENT. IF YOU DO NOT AGREE WITH THESE TERMS, PROMPTLY NOTIFY NI AND RETURN THE PRODUCT UNUSED IN ITS ORIGINAL PACKAGING TO NI.

1. **PRICES AND ORDERS.** Prices are set forth in the quotation issued to Customer ("Quote"). All Quotes expire thirty (30) days from date of issuance, unless otherwise stated in the Quote. All orders are subject to acceptance at the sole discretion of NI. Orders will be considered accepted once NI books an order and sends Customer a sales order acknowledgement. NI shall not be bound by changes to an order unless agreed by NI in writing. NI reserves the right to cancel any order if any information provided by Customer to NI is inaccurate.

2. **PAYMENT AND INVOICING.** Payment is due at the time the order is placed. If Customer is approved for credit, payment shall be due within thirty (30) days from the date of invoice ("Invoice Date"). Payment shall be in the currency listed on the NI invoice. All sums not paid when due shall accrue interest daily at a monthly rate of the lesser of 1.5% or the highest rate permissible by law. If there are multiple un its in an order, each unit will be invoiced when shipped.

3. **DELIVERY, TITLE and RISK OF LOSS.** Title and risk of loss to Products (for Software, the media) shall pass to Customer upon shipment from NI, its warehouses, or its affiliated companies; provided however, NI retains a security interest and right of possession in the Products until Customer makes payment in full. For orders to be delivered within the same country as the NI entity accepting the order, NI will arrange the shipping; however, Customer is responsible for all shipping and handling fees set forth in the invoice. If Customer chooses to arrange for shipping or if the order is placed with an NI entity outside the country of the applicable shipping destination, Customer is responsible for all shipping and handling, including fees, customs, formalities and clearance. Shipment dates provided by NI are estimates only, and NI shall have no liability for losses or claims resulting from late delivery of Products. Claims for shipment shortage shall be deem ed waived unless presented to NI in writing within forty-five (45) days of Invoice Date.

4. **TAXES.** Prices exclude, and Customer is responsible for, any sales, use, service, value added, and like taxes ("Taxes") arising from the purchase of the Products and Services. If Customer is exempt from any Taxes, it must provide NI with the appropriate tax exemption documentation at the time the order is placed.

5. **SOFTWARE.** Software is licensed pursuant to the software license agreements provided with the software or, in the absence of such license agreements, the National Instruments Software License Agreement available at ni.com/legal at the time of purchase. All software is licensed, not sold, and title to the software remains with the applicable licensor(s).

6. **NON-NI BRANDED PRODUCTS.** Non-NI Branded Products that NI resells may not be testable or repairable by NI, and it may be necessary for Customer to contact the manufacturer or the publisher for service. NI does not warrant, has no obligation to support, and shall have no liability for Non-NI Branded Products. The Limited Warranty and NI Intellectual Property Liability sections of this Agreement do not apply to the sale and purchase of Non-NI Branded Products. "Non-NI Branded Product(s)" means any third-party hardware, software, or service that NI sells, but does not carry an NI mark.

7. **SERVICES.** Services provided by NI are also subject to any service agreements or statements of work agreed upon in writing by the parties or, as applicable, to the NI service terms and conditions, available at ni.com/legal/serviceterms.

8. **RETURN POLICY.** Customer may return standard Products within thirty (30) days of the Invoice Date. NI reserves the right to charge Customer a fifteen percent (15%) restocking fee for any Products returned to NI. No returns will be accepted after the thirty (30) day pe riod has expired. A Return Material Authorization (RMA) number is required for Customer to return any Products. Acceptance of returns of customized Products and Non-NI Branded Products is in the sole discretion of NI.

9. **LIMITED WARRANTY.** For a period of one (1) year from the Invoice Date, NI warrants that its Hardware will be free of defects in materials and workmanship that cause the Hardware to fail to substantially conform to the applicable NI published specifications. For a period of ninety (90) days from the Invoice Date, NI warrants that the Software (i) will perform substantially in accordance with the applicable documentation provided with the Software and (ii) the Software media will be free from defects in materials and workmanship. NI warrants that the Services will be performed in a good and workmanlike manner. If NI receives notice of a defect or non-conformance during the applicable warranty period, NI will, in its discretion: (i) repair or replace the affected Hardware or Software, (ii) re-perform the affected Services, or (iii) refund the fees paid for the affected Hardware, Software or Services. Repaired or replaced Hardware or Software will be warranted for the remainder of the original warranty period or ninety (90) days, whichever is longer. If NI elects to repair or replace Hardware, NI may use new or refurbished parts or products that are equivalent to new in performance and reliability and are at least functionally equivalent to the original part or Hardware. Customer must obtain an RMA number from NI before returning any Hardware under warranty to NI. Customer will pay shipping expenses to send the affected Hardware to NI, and NI will pay shipping expenses to return the Hardware to the Customer. If NI concludes, after examining and testing returned Hardware, that it is not covered by the Limited Warranty, NI will notify Customer and return the Hardware at Customer's expense. NI reserves the right to charge a fee for examining and testing Hardware not covered by the Limited Warranty. This Limited Warranty does not apply if the defect of the Hardware or Software

resulted from improper or inadequate maintenance, installation, repair, or calibration (performed by a party other than NI); unauthorized modification; improper environment; use of an improper hardware or software key; improper use or operation outside of the specification for the Hardware or Software; improper voltages; accident, abuse, or neglect; or a hazard such as lightning, flood, or other act of nature. THE REMEDIES SET FORTH ABOVE ARE EXCLUSIVE AND THE CUSTOMER'S SOLE REMEDIES, AND SHALL APPLY EVEN IF SUCH REMEDIES FAIL OF THEIR ESSENTIAL PURPOSE.

10. **NO OTHER WARRANTIES.** EXCEPT AS EXPRESSLY SET FORTH IN THIS AGREEMENT, PRODUCTS AND SERVICES ARE P ROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND AND NI DISCLAIMS ALL WARRANTIES, EXPRESSED OR IMPLIED, WITH RESPECT TO THE PRODUCTS OR SERVICES, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE OR NON-INFRINGEMENT, AND ANY WARRANTIES THAT MAY ARISE FROM USAGE OF TRADE OR COURSE OF DEALING. NI DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE OF OR THE RESULTS OF THE USE OF THE PRODUCTS OR SERVICES IN TERMS OF CORRECTNESS, ACCURACY, RELIAB ILITY, OR OTHERWISE. NI DOES NOT WARRANT THAT THE OPERATION OF THE PRODUCTS WILL BE UNINTERRUPTED OR ERROR FREE.

11. **WARNING AND CUSTOMER INDEMNITY.** CUSTOMER UNDERSTANDS AND ACKNOWLEDGES THAT PRODUCTS AND SERVICES ARE NOT DESIGNED, MANUFACTURED, OR TESTED FOR USE IN LIFE OR SAFETY CRITICAL SYSTEMS, HAZARDOUS ENVIRONMENTS OR ANY OTHER ENVIRONMENTS REQUIRING FAIL-SAFE PERFORMANCE, INCLUDING IN THE OPERATION OF NUCLEAR FACILITIES; AIRCRAFT NAVIGATION; AIR TRAFFIC CONTROL SYSTEMS; LIFE SAVING OR LIFE SUSTAINING SYSTEMS OR SUCH OTHER MEDICAL DEVICES; OR ANY OTHER APPLICATION IN WHICH THE FAILURE OF THE PRODUCT OR SERVICE COULD LEAD TO DEATH, PERSONAL INJURY, SEVERE PROPERTY DAMAGE OR ENVIRONMENTAL HARM (COL LECTIVELY, "HIGH-RISK USES"). FURTHER, CUSTOMER MUST TAKE PRUDENT STEPS TO PROTECT AGAINST PRODUCT AND SERVICE FAILURES, INCLUDING PROVIDING BACK-UP AND SHUT-DOWN MECHANISMS. NI EXPRESSLY DISCLAIMS ANY EXP RESS OR IMPLIED WARRANTY OF FITNESS OF THE PRODUCTS OR SERVICES FOR HIGH-RISK USES. CUSTOMER SHALL DEFEND, INDEMNIFY, AND HOLD NI HARMLESS FROM ANY AND ALL CLAIMS, LOSSES, DAMAGES, ACTIONS, INCLUDING, LAWSUITS, ARBITRATIONS, AND/OR ADMINISTRATIVE ACTIONS, AND EXPENSES (INCLUDING REASONABLE ATTORNEYS' FEES) ARISING OUT OF CUSTOMER'S USE OF THE PRODUCTS AND SERVICES FOR ANY HIGH-RISK USES, INCLUDING CLAIMS FOR PRODUCT LIABILITY, PERSONAL INJURY (INCLUDING DEATH) OR DAMAGE TO PROPERTY, REGARDLESS OF WHETHER SUCH CLAIMS ARE FOUNDED IN WHOLE OR IN PART UPON ALLEGED OR ACTUAL NEGLIGENCE OF NI.

12. **SYSTEM AND APPLICATION RESPONSIBILITY AND ADDITIONAL INDEMNITY.** CUSTOMER ACKNOWLEDGES THAT IT IS ULTIMATELY RESPONSIBLE FOR VERIFYING AND VALIDATING THE SUITABILITY AND RELIABILITY OF THE PRODUCTS OR SERVICES WHENEVER THE PRODUCTS OR SERVICES ARE INCORPORATED IN ITS SYSTEM OR APPLICATION, INCLUDING THE APPROPRIATE DESIGN, PROCESS, AND SAFETY LEVEL OF SUCH SYSTEM OR APPLICATION. FURTHER, CUSTOMER MUST TAKE PRUDENT STEPS TO PROTECT AGAINST PRODUCT AND SERVICE FAILURES WHEN PRODUCTS AND SERVICES ARE INCORPORATED IN A SYSTEM OR APPLICATION, INCLUDING PROVIDING BACK-UP AND SHUT-DOWN MECHANISMS. CUSTOMER SHALL DEFEND, INDEMNIFY, AND HOLD NI HARMLESS FROM ANY AND ALL CLAIMS, LOSSES, DAMAGES, ACTIONS, INCLUDING LAWSUITS, ARBITRATIONS, AND/OR ADMINISTRATIVE ACTIONS, AND EXPENSES (INCLUDING REASONABLE ATTORNEYS' FEES) ARISING OUT OF CUSTOMER'S INCORPORATION OF THE PRODUCTS OR SERVICES INTO ITS SYSTEM OR APPLICATION, REGARDLESS OF WHETHER SUCH CLAIMS ARE FOUNDED IN WHOLE OR IN PART UPON ALLEGED OR ACTUAL NEGLIGENCE OF NI.

13. **INTELLECTUAL PROPERTY LIABILITY.** NI agrees to defend any third-party claim that alleges the Hardware, Software or Services infringe any U.S. patent, copyright, or trademark ("Claim"). Customer shall notify NI immediately upon learning of any Claim, or any allegation that the grounds for a Claim may exist, shall grant NI sole control over the defense and settlement of the Claim, and shall cooperate fully with NI in preparing a defense for any Claim. NI agrees to pay any final judgment or settlement resulting from any Claim, provided that the settlement is entered into in accordance with this Section. NI shall not be liable for a settlement made without its prior written consent. Notwithstanding the foregoing, NI shall have no obligation under this Section for any claim relating to or arising from (a) Customer's modifications of Hardware, Software or Services; (b) failure to use Hardware, Software or Services in accordance with the applicable documentation provided by NI; (c) the combination, operation, or use of Hardware, Software or Services with any hardware, software or service not provided by NI; (d) the compliance of NI with Customer's specifications or directions, including the incorporation of any software or other materials provided by or requested by Customer; or (e) Non-NI Branded Products. The foregoing states the Custom er's sole remedy for, and the entire liability and responsibility of NI for, infringement of any patent, trademark, or copyright or other intellectual property rights. THIS LIMITED INDEMNITY IS IN LIEU OF ANY OTHER STATUTORY OR IMPLIED WARRANTY AGAINST INFRINGEMENT. In any event, if NI believes in its reasonable opinion the Hardware, Software, or Services may be alleged to be infringing, for the purposes of mitigating any potential damages, NI may, at its option, (i) procure for the Customer the right to continue to use the Hardware, Software, or Services; (ii) replace them with comparable Hardware, Software or Services that are free of such infringe ment; or (iii) refund the fees paid by Customer, in which case Customer shall promptly return the Hardware to NI and/or terminate the use of the Software or Services.

14. **PROPRIETARY RIGHTS.** NI reserves all right, title, and interest in any intellectual property rights contained or embodied in Products, or resulting from the Services, including any custom developments created or provided by NI under this Agreement. Nothing in this Agreement will be deemed to grant to Customer any ownership rights in such intellectual property.

15. **LIMITATION OF LIABILITY.** NI SHALL NOT BE LIABLE FOR (I) SPECIAL, INDIRECT, INCIDENTAL, PUNITIVE, EXEMPLARY, OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR IN CONNECTION WITH THIS AGREEMENT OR THE PRODUCTS OR

SERVICES; OR (II) ANY DAMAGES ARISING OUT OF OR IN CONNECTION WITH: (A) PRODUCTS OR SERVICES NOT BEING AVAILABLE FOR USE, INCLUDING ANY COSTS OF OBTAINING SUBSTITUTE PRODUCTS OR SERVICES; (B) LOSS OF, CORRUPTION OF, OR LOSS OF USE OF ANY PRODUCTS, HARDWARE, SOFTWARE OR DATA; (C) LOSS OF REVENUE, PROFIT, OR BUSINESS OPPORTUNITY; (D) BUSINESS INTERRUPTION OR DOWNTIME; OR (E) INABILITY TO ACHIEVE A PARTICULAR RESULT, EVEN IF IT IS AT SUGGESTION MADE BY NI. **T**O THE EXTENT PERMITTED BY APPLICABLE LAW, THE TOTAL LIABILITY OF NI ARISING OUT OF, OR IN CONNECTION WITH THIS AGREEMENT OR THE PRODUCTS OR SERVICES, SHALL NOT EXCEED THE AMOUNT OF THE FEES PAID BY CUSTOMER FOR THE SPECIFIC PRODUCT OR SERVICE GIVING RISE TO SUCH CLAIM. THIS SECTION: (1) APPLIES TO NI AND ITS LICENSORS, DISTRIBUTORS, AND SUPPLIERS (INCLUDING ITS AND THEIR DIRECTORS, OFFICERS, EMPLOYEES, AND AGENTS), (2) REFLECTS AN ALLOCATION OF RISK BETWEEN NI AND CUSTOMER IN VIEW OF THE PURCHASE PRICE OF THE PRODUCTS AND SERVICES, (3) APPLIES EVEN IF NI HAS BEEN ADVISED OF THE POSSIBILITY OF THE DAMAGES AND REGARDLESS OF WHETHER SUCH CLAIMS ARE FOUNDED IN WHOLE OR IN PART UPON ALLEGED OR ACTUAL NEGLIGENCE OF NI, AND (4) REGARDLESS OF WHETHER SUCH DAMAGES ARE BASED IN CONTRACT, WARRANTY, STRICT LIABILITY, NEGLIGENCE, TORT, OR OTHERWISE. TO THE EXTENT THE FOREGOING LIMITATION OF LIABILITY IS UNENFORCEABLE OR FAILS OF ITS ESSENTIAL PURPOSE, THE SOLE LIABILITY OF NI TO CUSTOMER SHALL BE LIMITED TO $50,000 (USD).

16. **FORCE MAJEURE.** NI shall not be responsible for any delay or failure to perform due to any cause beyond its reasonable control, including but not limited to acts of nature or governments; interruptions of telecommunications, power or transportation; failure of contractors or suppliers; or inability to obtain necessary labor or materials ("Force Majeure Event"). In the event of a Force Majeure Event, NI reserves the right to cancel the applicable order without any liability to Customer.

17. **EXPORT AND SANCTIONS LAWS AND COMPLIANCE.** Products (which, for purposes of this Section, shall include the software and technology incorporated in or supplied with a Product and Service) purchased from NI are subject to control under the U.S. Export Administration Regulations (15 CFR Part 730 et. seq.) administered by the U.S. Department of Commerce's Bureau of Industry and Security ("BIS") (www.bis.doc.gov) and other applicable U.S. export control laws and sanctions regulations, including those administered by the U.S. Treasury Department's Office of Foreign Assets Control ("OFAC") (www.treas.gov/ofac). In addition, Products distributed from NI's distribution center in Europe are subject to control under the European Union ("EU") Council Regulation No. 428/2009 and their export or intra-EU transfer may also be subject to additional licensing requirements under European Union Council Regulation No. 428/2009 and its implementing regulations. Products may not be exported or re-exported to any country where sanctions are imposed by the U.S. government (which currently includes Cuba, Iran, North Korea, Republic of Sudan and Syria but which may be modified by the U.S. government from time to time). Customer agrees it will comply with the export laws and trade sanctions of all applicable countries and will not export, re-export or transfer Products purchased from NI without the required license(s), including an export or re-export license issued by the U.S. authorities, or to any prohibited destination or for a prohibited end-use. Products may also require export license(s) issued by the applicable authorities before being returned to NI. The issuance of a Quote, a sales order acknowledgment, or an RMA by NI is not an export license. Customer represents and warrants it is not ineligible or otherwise restricted by U.S. or applicable law to receive Products and it will not export, re-export, or provide Products to any person or entity on OFAC's List of Specially Designated Nationals or on BIS's Denied Persons List, Entity List or Unverified List or any other applicable restricted party list. NI reserves the right to refuse and/or cancel any order if, at any time, NI believes that any export controls or trade sanctions laws may be violated. See ni.com/legal/export-compliance for more information.

18. **GOVERNING LAW.** This Agreement shall be governed by the laws of the State of Texas, U.S.A., without regard to principles of conflicts of laws. The parties submit to the personal jurisdiction of the state and federal courts in Travis County, Texas. The parties expressly agree that the provisions of the United Nations Convention on Contracts for the International Sale of Products will not apply to this Agreement.

19. **LIMITATION PERIOD.** NI SHALL NOT BE LIABLE FOR ANY CLAIM ARISING UNDER THIS AGREEMENT BROUGHT MORE THAN TWO YEARS AFTER THE CAUSE OF ACTION FOR SUCH CLAIM FIRST AROSE.

20. **UPDATES.** NI reserves the right to update this Agreement at any time, effective upon posting an updated version at ni.com/legal/termsofsale; however, the terms and conditions in effect at the time of purchase shall apply to that purchase of Products or Services.

21. **GENERAL TERMS.** This Agreement, and any terms incorporated herein by reference, constitutes the entire Agreement between the parties with respect to the subject matter hereof and supersedes all prior understandings or agreements, whether written or oral, with respect to that subject matter. Customer acknowledges reading this Agreement, understands these terms, and agrees to be bound by them. This Agreement may not be altered, supplemented, or amended by the use of any other document unless otherwise agreed in writing by NI. No delay or failure by NI to exercise any right it has under this Agreement shall impair or be construed as a waiver of such right. A waiver of any provision of this Agreement must be in writing and shall not be construed as a waiver or modification of any other term hereof, or as a continuing waiver of any provision. The term 'including' as used in the Agreement should be construed as 'including without limitation'. If any part, term, or provision of this Agreement is held illegal, unenforceable, or in conflict with any applicable and enforceable law, the validity of the remaining portions or provisions of this Agreement shall not be affected. The doctrine that any ambiguity contained in a contract shall be construed against the party whose counsel has drafted the contract is expressly waived by each of the parties with respect to this Agreement.

November 1, 2012

QUOTE

680 Birch Street, Saint-Lambert, (Quebec) J4P 2N3
T. 450-465-1113 F. 450-465-1938

Doc N° PB-RTTQ4390

Date 2015/11/24

Bill to	Ship to
University of Tennessee, Knoxville Civil Enginee Sihem Le Pape 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** sihem.lepape@gmail.com	**University of Tennessee, Knoxville Civil Engineeri** Sihem Le Pape 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** sihem.lepape@gmail.com

Salesperson	Incoterm	Payment Terms	Currency
Polly Brown	EXW Saint-Lambert	TBD	US$

Availability	Validity	Shipping Method
	1 month	To be defined

#	Item Number	Description	Qty	Unit	Unit Price	Total Price
		FBG with specific coating for alkali protection - MuST				
1		**SOFO Sensors**				
1.1	10.1010.LAS-nn	SOFO Standard Deformation Sensor Active Length, Standard (meters) {0.2 - 2}	1	ea	555.00	555.00
1.2	10.1010.LPS-nn	Standard Cable (price per meter) {1.4 - 2000}. For lengths L>100m,ask for delivery terms	10	ea	3.00	30.00
1.3	10.1010.GNS	With standard Gland Nut PG11	1	ea	0.00	0.00
2		**Accessories (optional)**				
2.1	40.1025	Long gage sensors Surface Installation Kit (inclues 1 drill every 12 L-Brackets)	0	ea	5.80	0.00
2.2	40.1025.BRalu	Alluminum L-Brackets (2x) (incl. 4x M6x50 bolts)	0	ea	113.00	0.00
2.3	40.1025.BRsst	Stainless steel L-Brackets (2x) (incl. 4x M6x50 bolts)	0	ea	126.00	0.00
2.4	40.1025.dd	4x Deep drilling bolts (M6x100) instead of normal bolts	0	ea	0.00	0.00
2.5	40.1025.pl	Stainless steel plate for gluing/welding (2x)	0	ea	149.00	0.00
3		**Reading Units**				
3.1	10.2011.CH8	SOFO/MuST VII Universal Reading unit 8ch, outdoor Box, integrated PC, static measurements SOFO or MuST sensors (user selectable by channel), Ethernet connection, SDB Pro software	1	ea	40075.00	40075.00
3.2	10.2011.sp	SOFO Splitter to connect up to 5 SOFO sensor to the same SOFO VII channel	0	ea	1250.00	0.00
	SR-TRANSPORT	Transport fees to be determined at time of shipping	1	ea	0.00	0.00

Subtotal	40,660.00
GST	0.00
PST	0.00
Shipping	0.00
Total	**US$40,660.00**

Approved by : _____

We are pleased to submit the above quotation for your consideration. This quote is subject to and expressly conditioned upon customer's acceptance of Roctest Ltd.("Roctest") standard Terms and Conditions located at www.roctest.com/terms as evidenced by customer's issuance of a purchase order for product(s), customer's acceptance of any product under the purchase order, or customer's payment for any product under the purchase order. Additional or different Terms & Conditions (including those that may be contained in customer's purchase order) shall be void and of no effect unless a written agreement to the contrary is provided by Roctest. Any commodities, technology or software covered by this quote will be transferred or exported in accordance with Canadian Export Laws as well as U.S. Export Administration Regulations and the Foreign Assets Control Regulations as required. Diversion contrary to Canadian or U.S. law is prohibited.

Quotation

8751

303 Anderson Street
College Station, TX 77840

Phone: (979) 764-0442 sales@straingage.com
Fax: (979) 696-2390 www.straingage.com

Date: 12/18/2015

Quote To: University of Tennessee

Contact: Nolan Hayes

Contact Info:

From: Amy Persyn

We are pleased to offer the following quotation:

Qty	Item	Description	Price	Total
64	KM-100B	Strain Gage (each)	292.00	18,688.00
	Sales Discount	10% Discount	-10.00%	-1,868.80
12	KM-100BT	Strain Gage (each)	322.00	3,864.00
	Sales Discount	10% Discount	-10.00%	-386.40

Quote valid for 30 days.

Shipping from Texas Measurements, Inc. to destination will be prepaid and added to the invoice. We accept Visa, MasterCard and purchase orders. Payment terms for purchase orders are Net 30.

An exact delivery date can be provided upon request after placing order.

Please note: we cannot accept returns. All sales are final. Should you have any questions about the product(s) you wish to order, our technical manager will be happy to assist you in making the right selection.

THANK YOU!

Total $20,296.80

680 Birch Street, Saint-Lambert, (Quebec) J4P 2N3
T. 450-465-1113 F. 450-465-1938

QUOTE

Doc N° PB-RTTQ4531

Date 2016/01/13

Bill to	Ship to
University of Tennessee, Knoxville Civil Enginee Nolan WEsley Hayes 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** nhayes3@vols.utk.edu	**University of Tennessee, Knoxville Civil Engineeri** Nolan WEsley Hayes 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** nhayes3@vols.utk.edu

Salesperson	Incoterm	Payment Terms	Currency
Polly Brown	EXW Saint-Lambert	TBD	US$

Availability	Validity	Shipping Method
	1 month	To be defined

#	Item Number	Description	Qty	Unit	Unit Price	Total Price
		ELectrical TPC				
	FR-1078F50100	TPC cell 229mm with electrical pressure transducer for IRC-41A type of pressure transducer (0-5V or 4-20mA) and range to be specified at time of order	1	un	1170.00	1170.00
	NS-TPC100x200	TPC rectangular cell 100 x 200mm with electrical pressure transducer for IRC-41A type of pressure transducer (0-5V or 4-20mA) and range to be specified at time of order	1	un	1170.00	1170.00
	NS-TPC150x250	TPC rectangular cell 150 x 250mm with electrical pressure transducer for IRC-41A type of pressure transducer (0-5V or 4-20mA) and range to be specified at time of order	1	un	1240.00	1240.00
	NS-TPC200x300	TPC rectangular cell 200 x 300mm with electrical pressure transducer for IRC-41A type of pressure transducer (0-5V or 4-20mA) and range to be specified at time of order	1	un	1330.00	1330.00
	CA-IRC41A-ft	IRC-41A cable, 2 shielded pairs (22 AWG) cable length to be specified at time of order 10 foot minumum per sensor	10	ft	0.63	6.30
		Accessories				
	20-1078E02020	1.2 meter length repressurization tube (optional)	0	un	102.00	0.00
	SR-TRANSPORT	Transport fees to be determined at time of shipping	1	ea	0.00	0.00

#	Item Number	Description	Qty	Unit	Unit Price	Total Price

Subtotal	4,916.30
GST	0.00
PST	0.00
Shipping	0.00
Total	**US$4,916.30**

Approved by : _____

We are pleased to submit the above quotation for your consideration. This quote is subject to and expressly conditioned upon customer's acceptance of Roctest Ltd.("Roctest") standard Terms and Conditions located at www.roctest.com/terms as evidenced by customer's issuance of a purchase order for product(s), customer's acceptance of any product under the purchase order, or customer's payment for any product under the purchase order. Additional or different Terms & Conditions (including those that may be contained in customer's purchase order) shall be void and of no effect unless a written agreement to the contrary is provided by Roctest. Any commodities, technology or software covered by this quote will be transferred or exported in accordance with Canadian Export Laws as well as U.S. Export Administration Regulations and the Foreign Assets Control Regulations as required. Diversion contrary to Canadian or U.S. law is prohibited.

680 Birch Street, Saint-Lambert, (Quebec) J4P 2N3
T. 450-465-1113 F. 450-465-1938

QUOTE

Doc N° PB-RTTQ4156

Date 2015/09/21

Bill to	Ship to
University of Tennessee, Knoxville Civil Enginee Sihem Le Pape 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** sihem.lepape@gmail.com	**University of Tennessee, Knoxville Civil Engineeri** Sihem Le Pape 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** sihem.lepape@gmail.com

Salesperson	Incoterm	Payment Terms	Currency
Polly Brown	ExWorks St-Lambert, Qc	TBD	US$

Availability	Validity	Shipping Method
	1 month	To be defined

#	Item Number	Description	Qty	Unit	Unit Price	Total Price
		Rock dilatometer model PROBEX				
	FR-1037050100	PROBEX dilatometer probe and carrying case	1	un	22850.00	22850.00
	FR-1037008000	Tools and spares kit for PROBEX	1	un	1170.00	1170.00
	40-1037040500	Manual pump assembly for PROBEX	1	un	4950.00	4950.00
	40-1037040400K-m	Twin Tubing for Probex 100m specified for quotation purposes only (custom length available - kindly confirm at time of order) ~ Mounted with:	100	m	40.00	4000.00
	40-1037040400	Connectors for hydraulic twin tubing for Probex	1	un	500.00	500.00
	CA-IRC61A-m	IRC-61A cable, 3 pairs 22 AWG yellow polyurethane jacket 0.375 in	100	m	9.24	924.00
	40-1037040100	Electrical cable connectors	1	un	1260.00	1260.00
	20-1037002129	BW casing pin to AW rod box adaptor for the PROBEX	1	ea	380.00	380.00
	40-1037040200	Probex membrane	2	un	2500.00	5000.00
	20-1037002091	PROBEX Calibration Cylinder	1	un	445.00	445.00
	FR-1365050100	PROBOX readout unit for PROBEX pressuremeter	1	un	6070.00	6070.00
	NS-TECH	Roctest Field Services and Training Engineer: $125.00/hr - Includes all transportation time by the trainer (displacement to/from airport, airtravel, land transportation to/from site) - Site time (including stand by time): maximum 10 hrs/day - Report preparation (if required, to be requested by client at time of ordering) All expenses (airfare, logding, meals, ground transportation, misc.expenses) + 15% administration fee are invoiced upon trainer's return. When considering the purchase of a Pressuremeter, the training/field services is highly	1	ea	0.00	0.00

#	Item Number	Description	Qty	Unit	Unit Price	Total Price
		recommended.				
	20-1037002139	NQ rod pin to AW rod box adaptor for the PROBEX' (optional)	0	ea	380.00	0.00
	SR-TRANSPORT	Transport fees to be determined at time of shipping	1	ea	0.00	0.00
		SubTotal				47549.00
		Probex Rental				
		PROBEX BOREHOLE DILATOMETER *INCLUDING:* *Probe and manual pump* *Calibration tube* *Hydraulic Cable* *Electrical Cable* *Tool Kit & spare parts* *4 Liters Hydraulic fluid* *PROBOX Readout unit* *Instruction Manual*				
	SR-PREP	Preparation Fees	0	ea	500.00	0.00
	L-LRSEM	Weekly rental	0	ea	2850.00	0.00
	L-LRMOIS	Monthly Rental	0	ea	7500.00	0.00
		Field Services & Training				
	NS-TECH	Roctest Field Services and Training Travel time: $75.00/hr - Includes all transportation time by the trainer (displacement to/from airport, airtravel, land transportation to/from site) Site time: $125.00/hr - Site time (including stand by time): maximum 10 hrs/day - Report preparation (if required, to be requested by client at time of ordering) All expenses (airfare, logding, meals, ground transportation, misc.expenses) + 15% administration fee are invoiced upon trainer's return. When considering the purchase of a Pressuremeter, the training/field services is highly recommended.	0	ea	0.00	0.00

#	Item Number	Description	Qty	Unit	Unit Price	Total Price

Subtotal	47,549.00
GST	0.00
PST	0.00
Shipping	0.00
Total	**US$47,549.00**

Approved by : _____

We are pleased to submit the above quotation for your consideration. This quote is subject to and expressly conditioned upon customer's acceptance of Roctest Ltd.("Roctest") standard Terms and Conditions located at www.roctest.com/terms as evidenced by customer's issuance of a purchase order for product(s), customer's acceptance of any product under the purchase order, or customer's payment for any product under the purchase order. Additional or different Terms & Conditions (including those that may be contained in customer's purchase order) shall be void and of no effect unless a written agreement to the contrary is provided by Roctest. Any commodities, technology or software covered by this quote will be transferred or exported in accordance with Canadian Export Laws as well as U.S. Export Administration Regulations and the Foreign Assets Control Regulations as required. Diversion contrary to Canadian or U.S. law is prohibited.

QUOTE

680 Birch Street, Saint-Lambert, (Quebec) J4P 2N3
T. 450-465-1113 F. 450-465-1938

Doc N° PB-RTTQ4390

Date 2015/11/24

Bill to	Ship to
University of Tennessee, Knoxville Civil Enginee Sihem Le Pape 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** sihem.lepape@gmail.com	**University of Tennessee, Knoxville Civil Engineeri** Sihem Le Pape 325 John D. Tickle Building 851 Neyland Drive Knoxville, TN 37996-2313 US **Phone** 865-974-2503 **Fax** 865-974-2503 **Email** sihem.lepape@gmail.com

Salesperson	Incoterm	Payment Terms	Currency
Polly Brown	EXW Saint-Lambert	TBD	US$

Availability	Validity	Shipping Method
	1 month	To be defined

#	Item Number	Description	Qty	Unit	Unit Price	Total Price
		FBG with specific coating for alkali protection - MuST				
1		**SOFO Sensors**				
1.1	10.1010.LAS-nn	SOFO Standard Deformation Sensor Active Length, Standard (meters) {0.2 - 2}	1	ea	555.00	555.00
1.2	10.1010.LPS-nn	Standard Cable (price per meter) {1.4 - 2000}. For lengths L>100m,ask for delivery terms	10	ea	3.00	30.00
1.3	10.1010.GNS	With standard Gland Nut PG11	1	ea	0.00	0.00
2		**Accessories (optional)**				
2.1	40.1025	Long gage sensors Surface Installation Kit (inclues 1 drill every 12 L-Brackets)	0	ea	5.80	0.00
2.2	40.1025.BRalu	Alluminum L-Brackets (2x) (incl. 4x M6x50 bolts)	0	ea	113.00	0.00
2.3	40.1025.BRsst	Stainless steel L-Brackets (2x) (incl. 4x M6x50 bolts)	0	ea	126.00	0.00
2.4	40.1025.dd	4x Deep drilling bolts (M6x100) instead of normal bolts	0	ea	0.00	0.00
2.5	40.1025.pl	Stainless steel plate for gluing/welding (2x)	0	ea	149.00	0.00
3		**Reading Units**				
3.1	10.2011.CH8	SOFO/MuST VII Universal Reading unit 8ch, outdoor Box, integrated PC, static measurements SOFO or MuST sensors (user selectable by channel), Ethernet connection, SDB Pro software	1	ea	40075.00	40075.00
3.2	10.2011.sp	SOFO Splitter to connect up to 5 SOFO sensor to the same SOFO VII channel	0	ea	1250.00	0.00
	SR-TRANSPORT	Transport fees to be determined at time of shipping	1	ea	0.00	0.00

Subtotal	40,660.00
GST	0.00
PST	0.00
Shipping	0.00
Total	**US$40,660.00**

Approved by : _____

We are pleased to submit the above quotation for your consideration. This quote is subject to and expressly conditioned upon customer's acceptance of Roctest Ltd.("Roctest") standard Terms and Conditions located at www.roctest.com/terms as evidenced by customer's issuance of a purchase order for product(s), customer's acceptance of any product under the purchase order, or customer's payment for any product under the purchase order. Additional or different Terms & Conditions (including those that may be contained in customer's purchase order) shall be void and of no effect unless a written agreement to the contrary is provided by Roctest. Any commodities, technology or software covered by this quote will be transferred or exported in accordance with Canadian Export Laws as well as U.S. Export Administration Regulations and the Foreign Assets Control Regulations as required. Diversion contrary to Canadian or U.S. law is prohibited.

MISTRAS

Asset Protection Solutions

PRODUCTS & SYSTEMS DIVISION

195 Clarksville Road :: Princeton Junction, NJ 08550 USA
Phone: +1.609.716.4000 Fax: +1.609.716.0706
www.mistrasgroup.com

January 12, 2016

Paul Ziehl, PhD, PE
Professor
Dept. of Civil and Environ. Engineering
University of South Carolina
300 Main Street, C206
Columbia, SC 29208
Phone: 803 467 4030
e-mail: ziehl@cec.sc.edu

Re: Sensor Quotation
Quote # TD-16166 Rev B

The single most important factor in acoustic emission (AE) testing is the selection of the AE sensor (transducer). ***MISTRAS Group, Inc.*** prides itself on its ability to continually design and manufacture a diverse line of quality high sensitivity / low noise sensors to meet your particular needs. This capability is based on our solid tradition and expertise in the field of AE applications.

Our sensors actually "listen" to structures and materials to detect AE activity. Pressure vessels, storage tanks, heat exchangers, piping, reactors, aerial lift devices, and nuclear power plants are among the most common types of structures that are monitored. In all applications, AE sensors are vital links between the test structures and the analysis instrumentation, and their performance is critical to the success of every test.

AE sensors are available from ***MISTRAS Group, Inc.*** in various sizes, shapes, frequency and temperature ranges, and packaging styles in order to meet the diverse needs of the application and environment

Please see following page for equipment breakdown.

Item	Model & Desciption	Qty	Unit Price	Total price
	For use with the DiSP System			
001	***WDIC-AST,*** *pn# WDIC-AST,* Preamplified Sensor, Wideband (100 - 1000kHz), with 40 dB gain, AST, coated for outdoor use, 5 meter coaxial RG-58A/U cable, and connector (specify BNC, BNCR, SMB, SMBR, or Pigtail on the order).	16	$808.00	$12,928.00
002	***Magnetic Hold Down*** , *PN# Special-100* , Maghetic Hold Down for WDIC-AST Sensor	16	$225.00	$3,600.00
	Total			***$16,528.00***
			Plus Sales Tax (Where Applicable) & Shipping	

Optional

	For use with the Sensor Highway System			
003	***WDI-LP-AST,*** *pn# WDI-LP-AST* , Low Power, Preamplified Sensor, Wideband (100 - 1000kHz), with 26 dB gain, AST, coated for outdoor use, 5meter coaxial RG-58A/U cable, and connector (specify BNC, BNCR, SMB, SMBR, or Pigtail on the order).	16	$808.00	$12,928.00
004	***Magnetic Hold Down*** , *PN# Special-100* , Maghetic Hold Down for WDI-LP-AST Sensor	16	$225.00	$3,600.00
	Total			***$16,528.00***
			Plus Sales Tax (Where Applicable) & Shipping	

Sensor returns not permitted as they are calibrated and cannot be returned to stock after shipping

You may also download our Sensor Summary Chart off of our website for Sensor Specifications. www.mistrasgroup.com

Validity:	*90 Days*
Payment Terms:	*Net 30 days upon approval by Accounting. We also accept credit cards, (VISA, MasterCard & American Express)* ***NOTE:*** *there will be a 3% processing fee levied on total of order when using a credit card for orders of $5000.00 or over.*
Tax Terms	**Mistras Group, Inc. is now adding all applicable sales tax, on equipment orders sold, on our invoices. Your local state, city or county tax will automatically be charged unless a tax exempt or re-sale certificate has been submitted**
Delivery:	*30 Days ARO*
FOB:	***Princeton Junction, NJ , Buyer understands that he/she is responsible for shipment, insurance and any damages caused by shipping, from the FOB Shipping Point.***
Ship Via:	*UPS Ground* ***PP & Add to invoice*** *or collect with customers account number*
Origin:	*Made in USA*
Minimum Order:	*$100*
Place an Order:	*Please submit documents to sales.systems@mistrasgroup.com or by fax to 609-716-0706*

"BUY AMERICAN"
"Help keep Americans Employed"

I trust that the specifications and options are clear, but if you have any questions or comments, please do not hesitate to call. We appreciate your inquiry and look forward to doing business with you in the near future. If you visit our website www.mistrasgroup.com there is also some helpful information on the web.

Best regards,

Terry Tamutus

Terry Tamutus
AE Regional Sales Manager – Northeast &
Director of Infrastructure Business Development
Products & Systems Division
Mistras Group, Inc.
P: 609-468-5737
E: terry.tamutus@mistrasgroup.com

<TAT/eg>

MISTRAS GROUP, INC.
GENERAL TERMS AND CONDITIONS OF SALE

1) Acceptance of customer's order is expressly made conditional on assent to the terms and conditions set forth herein and on attachment(s) hereto and they shall constitute the complete agreement between the parties. These terms and conditions may not be varied, or Customer's order terminated in any manner unless by written agreement signed by an officer of Mistras Group, Inc. (also referred to herein as "MISTRAS" or "the Company"). Other representatives of the Company are not authorized to vary the conditions herein set forth. Failure to specifically dissent to these terms and conditions or customer's acceptance of any goods covered by this acknowledgment shall constitute acceptance of said terms and conditions and they shall be controlling in every case.
2) Unless otherwise specified in writing, all proposals expire ninety (90) days from the date of proposal.
3) Unless stated to the contrary on the face hereof, all goods furnished hereunder will be shipped F.O.B. point of shipment, and title in and the right of possession to such goods pass to the customer upon the company's delivery to carrier at point of shipment. Any loss in transit after FOB shipment is the sole responsibility of the customer.
4) Unless specified otherwise in writing by MISTRAS, payment terms are net cash, payable without offset, in US dollars, with approved credit, paid 30 days from the date of invoice.
5) Purchaser shall pay, in addition to any overdue payment, a late charge of 1.5% per month, on all overdue amounts plus any collection fees, MISTRAS attorney fees and, court costs in connection to collection.
6) Tooling, set-up, fitting-up, drawings, design information and partial preparation charges when invoiced cover only part of the cost thereof to the company. The customer does not acquire any right, title or interest in any tooling, set-up, fitting-up, drawings, design information, or invention resulting therefrom.
7) Any inspection by the Purchaser of Equipment on MISTRAS premises shall be scheduled in advance and performed during normal working hours.
8) Any partial payments due to MISTRAS based on meeting specific measurable milestones, these invoices/payments represent work completed by MISTRAS and rightfully earned and owned by MISTRAS, without any recourse.
9) If the order provides for site acceptance testing to verify that the equipment has arrived at the site complete, without physical damage, and in good operating condition, completion of site acceptance test constitutes full and final acceptance of the equipment. If, through no fault of MISTRAS, acceptance testing in not completed within thirty (30) days after arrival of the equipment at the site, the site acceptance test shall be deemed completed and the equipment shall be deemed accepted and any remaining payments due MISTRAS will be paid by the buyer.
10) All shipping dates are tentative. The company will not be responsible for delays of non-performance directly or indirectly caused by governmental regulations or requirements, act of God, unavailability of materials, work stoppages, slow downs, boycotts, and other causes (whether or not similar in nature to any of these hereinbefore specified) beyond the company's reasonable control.
11) This company's line of products requires close coordination of the customer's requirements with the company's production schedules to avoid possible delays in shipment. Accordingly, the company reserves the right to ship approximately thirty days in advance of shipping date.
12) THERE IS NO WARRANTY BY THE COMPANY THAT THE GOODS SHALL BE DELIVERED free from any claim of any third person by way of infringement of Trademarks, Patents or Copyrights.
13) Seller warrants that the articles delivered or used hereunder shall be free from defects in material, workmanship and fabrication. This WARRANTY shall extend for a period of one (1) year after date of delivery of such articles to Buyer. SELLER MAKES NO WARRANTY, EXPRESS, IMPLIED (INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY AND FITNESS FOR INTENDED PURPOSE), OR STATUTORY, OTHER THAN THE FOREGOING EXPRESS WARRANTY. Failure of Buyer to submit any claim hereunder within ninety (90) days after receipt of such articles shall be an admission by Buyer and conclusive proof that such articles are in every respect as warranted and shall release Seller from any and all claims for damage or loss sustained by Buyer, in the event Buyer timely submits a claim for breach of WARRANTY, the parties agree that Buyer's role and exclusive remedy shall be the repair or replacement of such defective article. IN NO EVENT SHALL SELLER BE LIABLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGE OF THE PURCHASER, USER OR THIRD PARTIES. Seller's warranties shall inure to the benefit of the original user only.
14) Factory service by personnel from the United States for loaned or purchased items, if required, is available at a charge of prevailing labor rate per man-day, plus expenses and parts. Spare and replacement parts for the tool(s), and/or machine(s), and/or applicator(s), can be purchased from the company.
15) The company shall have the right to suspend or cancel this agreement at any time upon customer making an assignment for the benefit of creditors or becoming bankrupt or insolvent, or upon a petition being filed in a court of competent jurisdiction proposing the appointment of a receiver or that the customer be adjudicated bankrupt or insolvent or reorganized under the provisions of any applicable bankruptcy or insolvency act.
16) The company represents that with respect to the production of the articles and/or the performance of the services stated herein, it has fully complied with all the applicable provisions of the Fair Labor Standards Act of 1938, as amended, including section 6, 7 and 12, regulations under section 14, and all other applicable Administrative Regulations.
17) Any order may be cancelled before shipment by Purchaser only upon written notice and payment of termination charges, including but not limited to, all costs identified to the order incurred prior to the effective date of notice of termination and all expenses incurred by MISTRAS attributable, plus a fixed sum of fifteen (15) percent of the final total price to compensate for disruption in scheduling, planned production and other indirect costs.
18) MISTRAS warrants that, except as specified below, the software will, when properly installed, execute in accordance with MISTRAS's specification. If a nonconformity to the foregoing warranty is discovered during the period ending one (1) year after date of shipment and written notice of such

nonconformity is provided to MISTRAS promptly after such discovery and within that period, including a description of the nonconformity and complete information about the manner of the discovery, MISTRAS shall correct the nonconformity by, at its option, either (i) modifying or making available to the Purchaser instructions for modifying the Software, or (ii) making available at MISTRAS's facility necessary corrected or replacement programs. MISTRAS shall have no obligation with respect to nonconformities resulting from (i) unauthorized modification of the Software or (ii) Purchaser-supplied software or interfacing. MISTRAS does not warrant that the functions contained in the software will operate in combinations which may be selected for use by the Purchaser, or that the software products are free from errors in the nature of what is commonly categorized as "bugs". MISTRAS owns all rights in or has right to sublicense all of the software, if any, to be delivered to Purchaser under this Agreement. As part of this sale made hereunder Purchaser hereby obtains a limited license to use Software, subject to the following: (i) the software may be used only in conjunction with Equipment specified or approved by MISTRAS, (ii) the software shall be kept strictly confidential, (iii) the software shall not be copied, reverse engineered, or modified, (iv) the Purchaser's right to use the software shall terminate immediately when specified equipment is no longer used by the Purchaser or when otherwise terminated and (v) the rights to use the software are non-exclusive and non-transferrable, except with MISTRAS prior written consent.

19) In addition to the rights and remedies reserved herein, the Company shall have all rights and remedies conferred by law and shall not be required to proceed with performance for the contract arising herefrom if customer is in default to the company under this or any other contract. This agreement shall be construed in accordance with the laws of the State of New Jersey, U.S.A.
20) The prices stated in this acknowledgment do not include, unless specifically stated, any special processing charges (e.g. Letters of Credit, wire transfer fee's, bank fees, etc.), credit card charges, sales, use or other taxes and if such are payable in connection with this order they shall become an additional charge to the Purchaser.
21) In no event shall MISTRAS, its suppliers or subcontractors be liable for special, indirect, incidental, or consequential damages, whether in contract, warranty, tort, negligence, strict liability or otherwise, including, but not limited to, loss of profits or revenue, loss of use of the equipment or any associated equipment, cost of capital, cost of substitute equipment, facilities or services, downtime costs, delays, and claims of customers of the Purchaser or other third parties for any damages. MISTRAS liability for any claim whether in contract, warranty, tort, negligence, strict liability, or otherwise for any loss or damage arising out of, connected with, or resulting from this agreement or the performance or breach thereof, or from the design, manufacture, sale, delivery, resale, repair, replacement, installation, technical direction of installation, inspection, operation or use of any equipment covered by or furnished under this agreement, or from any services rendered in connection therewith, shall in no case exceed one-half (1/2) of the purchase price allocable to the equipment or part thereof or services which gave rise to this claim.
22) This sales order acknowledgment constitutes SELLER'S offer to BUYER upon the terms and conditions stated herein and shall become a binding contract on the terms set forth herein when it is accepted by BUYER either by acknowledgement or by acceptance of the goods sold hereunder. By acceptance of the goods referred to herein BUYER thereby understands and agrees that SELLER will not and need not analyze any of the terms, conditions and other provisions contained in BUYER'S purchase order other than to determine the product or service ordered, quantities and shipping data. BUYER also agrees that SELLER may disregard all terms, conditions and provisions of any such purchase order that do not comply herewith and may fulfill such part of the terms, conditions, and provisions thereof as shall comply herewith. Any variation of the terms and conditions herein must be specifically accepted in writing by SELLER.

SCIENTIFIC
Second and Elm Streets
P.O. Box 248
Hudson, Wisconsin 54016
800-477-5253
715-386-2323
715-386-6149 FAX

Quotation

Quote No. NL1530467GA-A
Date : 12/08/2015

Customer	Med Rep
220001	for quotation purposes only
	P.O. Box 1828
	Newman, GA 30264
Attention	
Project	3-TN-UTK Environmental Chamber
Item Number	Budget Quotation
Rep Name	220 - Med Rep, Inc
Rep Number	220
Sales Specialist	Peter Wildes

	$	**Net**

(1) Nor-Lake ENVIROLINE 4.0 Walk-In Warm Room
52' 6" long, 24' 0" wide, 12' 3 5/8" high.

This full size Nor-Lake walk-in contains 14,476 internal cubic feet to assure maximum storage capacity. Compare to other quotes which may be nominal dimensions which can result in reduced storage space.

Refrigeration is “sized” for holding product only; that is; our calculation is based on product entering at the same temperature as the desired temperature of this walk-in. If you feel that this is insufficient, please advise.

GRAND TOTAL QUOTATION PRICE **$ 69,054**

Notes / Clarifications:
Approximate Total Shipping Weight (lbs) 14,039
Nor-Lake manufactures with environmentally friendly, CFC free, HFC 245fa polyurethane foam insulation.
Prices protected from increase through June 15, 2016. Prices void if purchase order, signed quote or print, and release for production are received later than June 15, 2016. All shipments FOB Hudson, WI. Based on the ship to address of this product, state sales tax maybe applicable. If applicable, sales tax will be added to the Nor-Lake invoice.
Acceptance of an order based on this quotation is subject to credit approval.
Please reference this Quotation Number on all correspondence.

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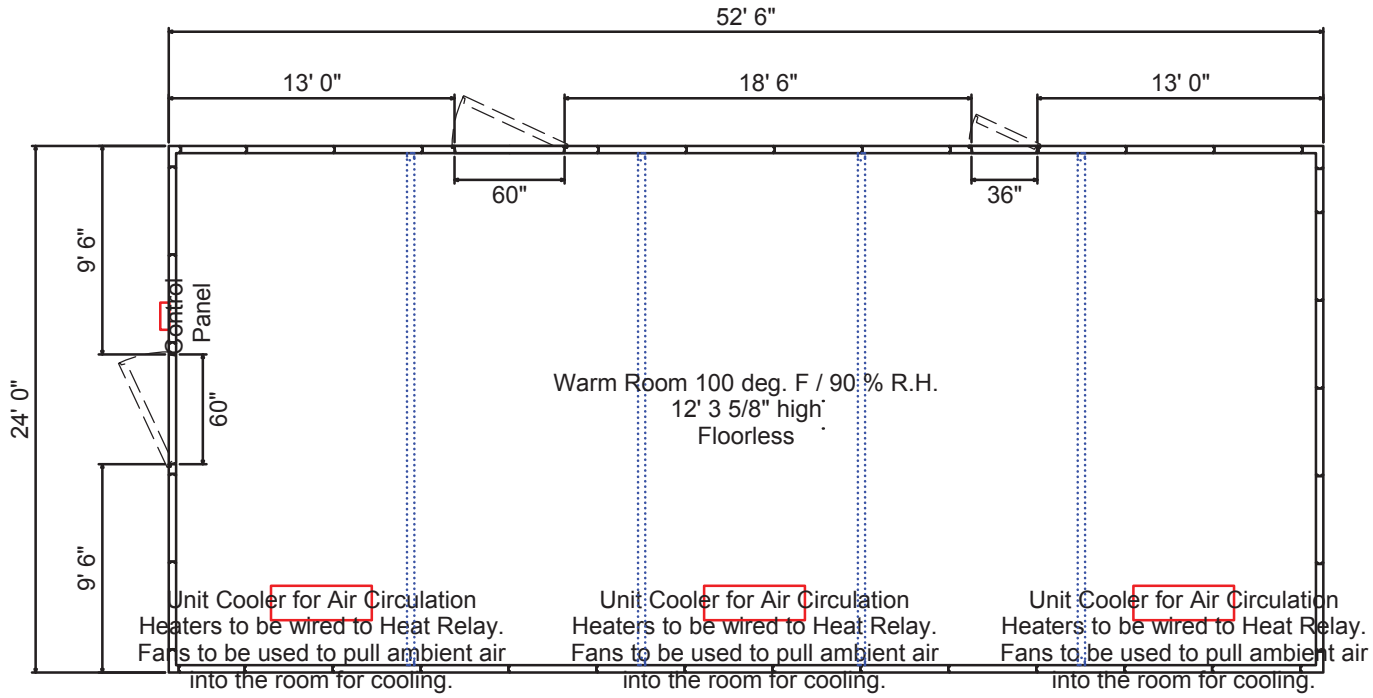
Item Number	Budget Quotation
Rep Name	220 - Med Rep, Inc
Rep Number	220
Sales Specialist	Peter Wildes

Prepared by: _____

Nor-Lake is registered by UL to ISO 9001-2008. California State Contractor License #940932.THIS BID, IF ACCEPTED, IS SUBJECT TO EXECUTION OF A WRITTEN CONTRACT OR PURCHASE ORDER.

(1) Nor-Lake ENVIROLINE 4.0 Walk-In Warm Room
52' 6" long, 24' 0" wide, 12' 3 5/8" high.

Finishes:
26 Gauge Corrosion Resistant Stucco Embossed Coated Steel - Interior wall, Exterior wall, Interior ceiling
26 Gauge Smooth Galvanized - Ceiling topside
1" Vinyl Floor Sealer for (1) Warm Room 100 deg. F / 90 % R.H.



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Rep Number	220
Sales Specialist	Peter Wildes

(1) 60" X 84" Walk-In Door right-hand swing
Includes door closer, cam lift hinges (one spring loaded), NL9800 deadbolt key/padlock handle with inside release, magnetic gasket, double sweep gasket & switch with pilot light.
(1) Four Way Light Switch With Pilot Light
(1) Door Through Panel Electrical; All Conduit Concealed Inside The Door Frame, Hole Pre-Drilled Through Ceiling And Field Installed Ceiling Mounted Junction Box With Conduit Provided.
(1) 60" X 84" Walk-In Door left-hand swing
Includes door closer, cam lift hinges (one spring loaded), NL9800 deadbolt key/padlock handle with inside release, magnetic gasket, double sweep gasket & switch with pilot light.
(1) Three Way Light Switch With Pilot Light
(1) Door Through Panel Electrical; All Conduit Concealed Inside The Door Frame, Hole Pre-Drilled Through Ceiling And Field Installed Ceiling Mounted Junction Box With Conduit Provided.
(1) 36" X 84" Walk-In Door left-hand swing
Includes door closer, cam lift hinges (one spring loaded), NL9800 deadbolt key/padlock handle with inside release, magnetic gasket, double sweep gasket & switch with pilot light.
(1) Three Way Light Switch With Pilot Light
(1) Door Through Panel Electrical; All Conduit Concealed Inside The Door Frame, Hole Pre-Drilled Through Ceiling And Field Installed Ceiling Mounted Junction Box With Conduit Provided.
(1) Beam W8x18 With (2) Posts For Indoor Use
(1) Beam W8x18 With (2) Posts For Indoor Use
(1) Beam W8x18 With (2) Posts For Indoor Use
(1) Beam W8x18 With (2) Posts For Indoor Use
(21) 48" Fluorescent, Vapor-Proof, Warm Room Light Fixture With T5 Bulbs And Electronic Ballast (Shipped Loose) 149449
(3) 6" Diameter x 5' Insulated Supply Pipe For Vent And Duct Air System With Elbow, Diffuser And Ceiling Opening.(one to be located behind each of the unit coolers for air circulation)
(3) 6" Diameter x 5' Insulated Exhaust Pipe For Vent And Duct Air System With Elbow, Diffuser And Ceiling Opening.
(6) Motorized Damper 6" Diameter (to be wired to the cooling relay)
(6) 6" Air Regulator 150CFM On Exhaust/Supply End

(1) Model CP8L Series Control Panel, U.L. Approved. CP8L Microprocessor Based Programmable Temperature Controller, Liquid Crystal Alphanumeric Display with 4x20 Character, Humidity Display, Simultaneous Product and Air Temp. Display, System Mode Indicator, High/Low Audio/Visual Alarm with Dry Contacts, System Over/Under Temp Safety Shutdown, Power Failure Alarm, Service Prompts, Password Entry System and Expandable for Communication Ports and Light Control. Key Locked Door with Viewing Cover, Circuit Breakers and 10" Temperature/Humidity Chart Recorder.
(1) Dixell XR30C Controller for High Limit Safety Shut Down

(2) Electric Steam Humidifier (Unducted); 5 KW@ 208-230/60/1 (Note:“The humidifier requires a water source with low mineral content; i.e., resistance of 0.05 - 1.0 megohm and a pressure of 10–100 psi. Reverse osmosis treated water is Recommended.")

(3) IFE26-130DE Unit Coolers for Heat and Air Circulation
Calculated load for 100 deg. F / 90 % R.H. is calculated from 50 deg. F / 50 % R.H. ambient , 70 deg. F . floor temperature (uninsulated floor), (1) 36" x 84" walk-in door and (2) 60" x 84" walk in doors opening into 50-80 deg. F . ambient, no air vent, no people working in the room, and no additional electrical load. All calculations are based on data supplied by ASHRAE publications.
Refrigeration is “sized” for holding product only; that is; our calculation is based on product entering at the same temperature as the desired temperature of this walk-in. If you feel that this is insufficient, please advise.

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Project	3-TN-UTK Environmental Chamber
Item Number	Budget Quotation
Rep Name	220 - Med Rep, Inc
Rep Number	220
Sales Specialist	Peter Wildes

Quotation is subject to change upon receipt of detailed specifications and/or refrigeration load information.

Clarifications:
* Price does not include taxes, bonding, shelving, factory testing, field testing, freight charges, or installation. Freight charges are included on an E-mail.
* No purchase can be made from this budget quotation.
* No refrigeration systems are included. Cooling is provided by ambient air around the room.
* Temperature uniformity is +/- 3 deg. F at the control sensor in lieu of +/- 2 deg. F.
* 90 % R.H is provided in lieu of 95 % R.H.
* Humidity accuracy is +/- 5 % R.H. at the control sensor.
* Two of the doors had to be moved to avoid the posts for the ceiling support.

Nor-Lake insurance and warranties per the enclosed attachments.
Contractor is responsible for field verification.
Price includes the following warranties: 18 month parts and labor, 15 year walk-in panel.
Nor-Lake bid is based upon the E-mail received on 12/1/15 only. Other Documents will be reviewed and their cost implications evaluated when these documents are sent to Nor-Lake for review. No addenda have been received.
Due to possible discrepancies, errors or omissions in the plans and specifications, only the items, sizes, and parameters noted on the individual room quotations are included in the Nor-Lake bid. The Nor-Lake quotation supersedes all other documents.
Nor Lake rooms offer a +/- 3 deg. F temperature uniformity at the control sensor.

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Quotation

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220001

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P.O. Box 1828
Newman, GA 30264

Project
3-TN-UTK Environmental Chamber

TERMS OF SALE

1. NATURE OF DOCUMENT. This document constitutes the acceptance of the members of the Standex Refrigerated Solutions Group ("Seller") to sell the products specified on the reverse side (the "Products") on the terms and conditions contained herein, however, acceptance is made expressly conditional on the Buyer's agreement to all of the terms and conditions contained herein. Seller's acceptance of a purchase order from the Buyer shall not constitute acceptance of any of the terms and conditions thereon which differ from these terms, except as the Seller may otherwise specify in writing. Such different or conflicting terms are expressly rejected by Seller.

2. CHANGES AND CANCELLATION. Seller shall have the right to terminate, modify and/or cancel the contract for sale of the Products at any time Seller determines that Buyer's credit is not satisfactory or for any other reason in Seller's reasonable commercial judgment. Any such termination or cancellation shall be effective upon notification (orally or in writing) to Buyer and shall be without liability to the Seller. Under no circumstances shall Buyer have the right to terminate the contract or cancel its order to purchase the Products, without written authorization by the Seller. All cancelled orders and returned goods will be subject to a minimum of 25% cancellation and/or restocking charge. Custom or modified units cannot be returned.

3. PRICES. Unless otherwise indicated, prices are F.O.B. Seller's facility, and do not include any sales, use, excise or similar taxes or duties now or hereafter imposed. Errors or omissions in prices are subject to correction. Prices are subject to change without notice prior to shipment.

4. PAYMENT. Unless otherwise indicated, payment terms are net cash 30 days from date of shipment. In the event that the Buyer fails to make payment on time, Buyer shall be liable to Seller for the lesser of (a) 1.5% per month on the remaining balance or (b) the highest monthly interest rate which may lawfully be charged to Buyer. Buyer shall be liable for all expenses (including reasonable attorneys' fees) incurred by Seller in collecting or attempting to collect any amounts due to Seller under the contract.

5. TITLE, RISK OF LOSS. Title to, and risk of loss of, the Products shall pass to Buyer upon the delivery of the Products F.O.B. Seller's facility to an agent of Buyer or to a common carrier.

6. INSPECTION. If, upon receipt of the Products by Buyer at the destination, the same shall appear not to conform to the order, Buyer shall within seven (7) days after receipt thereof, notify Seller of such condition and afford Seller a reasonable opportunity to inspect the Products and make the appropriate adjustments, repair or replacement. The remedies afforded under Section 7 below shall be exclusive for any defects discovered in the Products and which could have been discovered upon inspection. If the Seller is not so notified, the Buyer waives any recourse for those defects, and
all warranty obligations of Seller regarding such obvious defects or deficiencies shall terminate.

7. LIMITED WARRANTIES AND REMEDIES. Seller warrants that, at the time of shipment, the Products will be free from defects in material and workmanship to the original purchaser-user for a period no longer than one year from original installation by an authorized representative or one year and three months from shipment, under conditions of normal use and recommended maintenance. Written notice of a claim under this warranty must be received by Seller before the expiration of such period in order for warranty coverage to apply.
If notice of a claim is timely made, Seller will repair or replace the Product or part which is defective (at Seller's sole option) either at the user's facility or at Seller's plant, as Seller shall decide. If Seller decides that a Product or part should be returned to its plant, the Buyer or user shall have the following obligations:

(a) removal of any parts to be returned;
(b) identification of all parts with tags stating the model number and serial number of the Products on which the part is used;
(c) shipment of Products and/or parts, transportation prepaid, to Seller's plant;
(d) installation of the repaired or replaced Product or parts at user's facility.

This Warranty shall not apply to the extent that Products or parts have been used other than in conformance with operating or maintenance instructions, subjected to misuse or abuse, damaged by accident, act of God, abnormal use or stress or any other matter unrelated to Seller and beyond its reasonable control or altered or modified by third parties. **THIS WARRANTY IS EXCLUSIVE AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PURPOSE. IN NO EVENT SHALL THE COMPANY BE LIABLE FOR LOSS OF USE, REVENUE OR PROFIT OR FOR ANY OTHER INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGE, INCLUDING, BUT NOT LIMITED TO, FOOD SPOILAGE AND PRODUCT LOSS.**

8. LIMITATION OF LIABILITY. The liability of Seller arising out of the manufacture, sale, delivery, repair, or use of any of the Products shall not, in any event, exceed the cost of correcting defects or making replacement as required in the Limited Warranty and, upon the expiration of the Limited Warranty, all liability of Seller to Buyer and any end user shall terminate.

9. DELAYS. Neither party shall be liable for any delay or failure to perform any obligation to the other if such delay or failure shall be caused by an event or contingency beyond its reasonable control, irrespective of the nature thereof, however, the delaying party shall endeavor to correct such delay as soon as reasonably practicable.

10. MODIFICATION; ASSIGNMENT; APPLICABLE LAW; ENTIRE AGREEMENT. No modification of the terms and conditions specified in the contract shall be binding upon Seller unless agreed to by Seller in writing. The contract shall not be assigned by Buyer, nor may any of the duties of Buyer or User thereunder be delegated, without the written consent of Seller. Any such assignment or delegation without such consent shall be void. The contract shall be governed by, and construed in accordance with, the laws of the State of Delaware. The provisions of the contract shall constitute the entire agreement of the parties with respect to the sale of the Products by Seller to Buyer and shall supersede all prior discussion and writings between the parties.

11. BINDING EFFECT OF CONTRACT. The contract shall be binding upon, and shall inure to the benefit of the parties hereto and their respective successors and assigns.

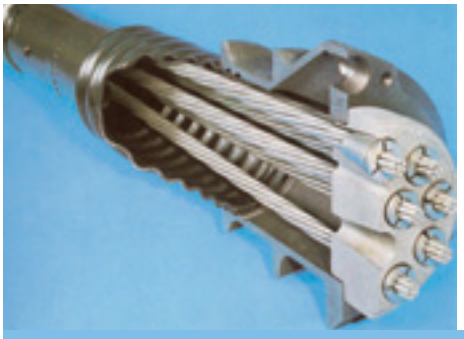
12. RETURNS. No returns will be accepted without the prior approval of the Seller. A Return Authorization Number must be given by Seller prior to Products being shipped, freight prepaid, by Buyer. Any damage in transit to Products being returned is Buyer's responsibility. All accepted returns are subject to a 25% restocking charge. Returns that have been approved by Seller must be received within thirty (30) days after approval. Returns will not be considered after ninety (90) days from date of original notice.

13. FREIGHT DAMAGES. Claims for damages must be filed at once by purchaser with the freight carrier although as a service to our customers we may act as their agent in seeking reimbursement under the applicable carrier insurance policy for the damage caused to the product in transit. Note: Any differences between the amount of the claim filed and the money received is a valid receivable that is the responsibility of the customer to remit to Standex Refrigerated Solutions Group.

14. INDEMNITY. Buyer or User agrees to indemnify, hold harmless and defend Seller from and against any and all liabilities and expenses arising out of any injury or damage which results from Buyer's or User's improper or abnormal use, misuse, misapplication, failure to inspect, maintain or repair the Products which are the subject of this agreement.

DYWIDAG-SYSTEMS INTERNATIONAL

DYWIDAG Post-Tensioning Systems
Multistrand Systems
Bar Systems
Repair and Strengthening



New Victory Bridge, Perth Amboy, NJ

DYWIDAG Post-Tensioning Systems

DYWIDAG Post-Tensioning Systems are world renowned for reliability and performance, most suitable for all applications in post-tensioned construction. They embrace the entire spectrum from bridge construction and buildings, to civil applications, above and below ground.

The first ever structure built with a prototype DYWIDAG Post-Tensioning System using bars was the Alsleben (Germany) arch-bridge in 1927. From that time on DYWIDAG has continuously improved its systems to keep up with the growing demand of modern construction technology. DYWIDAG-Systems International (DSI) offers a complete product line in strand and bar post-tensioning (bonded, unbonded and external) as well as stay-cables being able to fully serve the post-tensioning construction industry. DYWIDAG Post-Tensioning Systems have always combined the highest safety and reliability standards with the most economical efficiency in their research and development. Dependable corrosion protection methods incorporated into the DYWIDAG Post-Tensioning Systems contribute to the longevity of modern construction. High fatigue resistance is achieved with optimized material selection and careful detailing of all components especially in their system assembly.

St. Anthony Falls Bridge, Minneapolis, MN

DSI looks back on many years of valuable experience in the field of post-tensioning which leads to our extremely versatile product range that offers economical solutions for practically any problem. This includes our highly developed, most sophisticated field equipment which is easy to operate in all phases of installation including assembly, installation, stressing and finally grouting.

DYWIDAG Post-Tensioning Systems are being developed and maintained by DYWIDAG-Systems International and are serviced and distributed by a worldwide network of subsidiaries, licensees and agents. Our systems comply with the different national and international specifications and recommendations (ASTM, AASHTO, BS, Eurocode, DIN, Austrian Code, SIA, FIP, fib, EOTA, etc.).

DSI Scope of Services:

- consulting
- design and shop-drawing engineering
- manufacturing and supply
- installation or training and/or supervision of installation
- inspection and maintenance

Woodrow Wilson Bridge, Virginia Approach, Alexandria, VA

Pitt River Bridge, BC, Canada

Water Tanks, FL

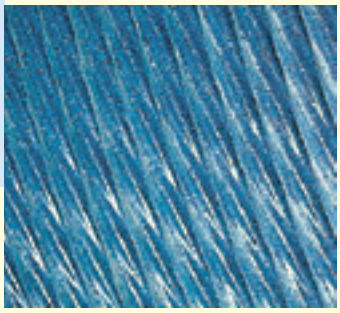
Contents

New Highlands-Sea Bright Bridge, New Jersey

Post-Tensioning System using Strand

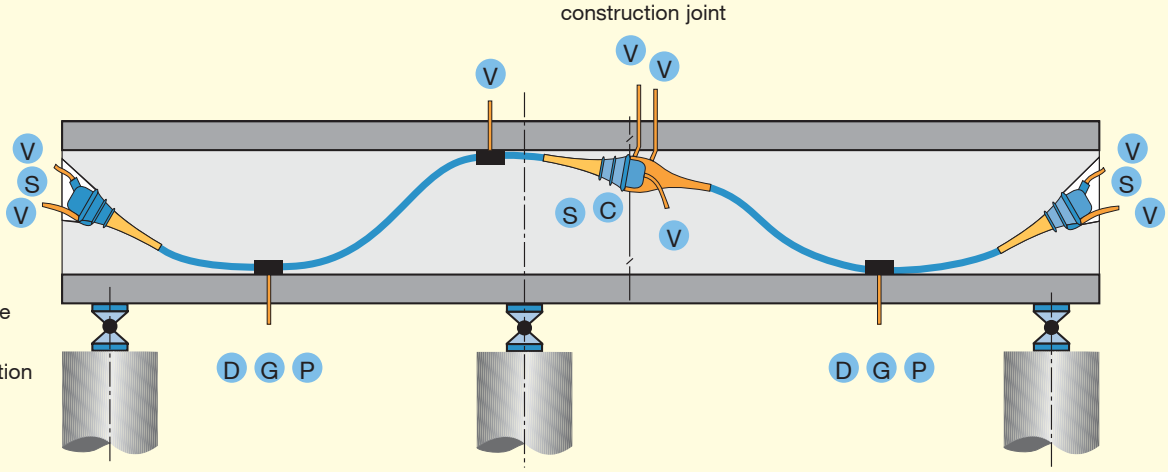
Strand is manufactured from 7 individual cold-drawn wires, 6 outer wires helically wound around one center wire (king wire). The mechanical properties of the strand as well as its corrosion protection are most important to DSI. Strand coatings do not affect the anchorage's capacity or efficiency. For improved corrosion protection we offer systems using polyethylene (PE) or polypropylene (PP) ducts.
See page 6.

Strand is normally packaged in calwrap coils that typically weigh up to 3.2 tons.



Epoxy Coated Strand

D = drain
V = vent
G = grout injection
C = coupler
S = stressing anchorage
P = post-grouting injection



▶ Technical Data

code/specification type		ASTM A 416 0.5“ (13 mm)	ASTM A 416 0.6“ (15 mm)		ASTM A 416 0.5“ (13 mm)	ASTM A 416 0.6“ (15 mm)
yield strength f_y [1]	(ksi)	243	243	(N/mm^2)	1,670	1,670
ultimate strength f_u	(ksi)	270	270	(N/mm^2)	1,860	1,860
nom. diameter	(in)	0.5	0.6	(mm)	12.7	15.24
cross-sectional area	(in2)	0.153	0.217	(mm^2)	98.71	140
weight	(lbs/ft)	0.52	0.74	(kg/m)	0.775	1.102
ultimate load	(kips)	41.3	58.6	(kN)	183.7	260.7
modulus of elasticity	(ksi)	28,000	28,000	(N/mm^2)	195,000	195,000
relaxation after [2] 1,000 h at 0.7 x 9013	(%)	2.5	2.5	(%)	2.5	2.5

[1] yield measured at 1% extension under load
[2] applicable for relaxation class 2 according to Eurocode prEN 10138/BS 5896: or low relaxation complying with ASTM A 416, respectively.

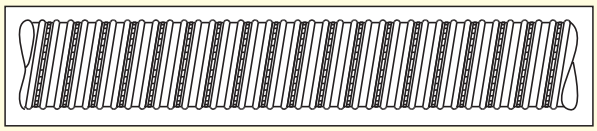
Epoxy coated strand used in the DYWIDAG Post-Tensioning Systems is Flo-Fill® where the interstices are filled with epoxy during the coating process providing exceptional corrosion protection. The epoxy coated strand conforms to ASTM A 882 with either a smooth or grit impregnated surface.

Corrugated Duct

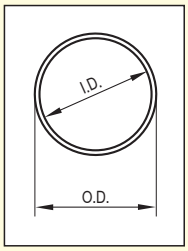
Corrugated metal ducts are the most economical means to create a void for the tensile elements. These thin-walled galvanized corrugated 28ga/0.38 mm - 24ga/0.61 mm sheet metal ducts also provide a secondary corrosion protection with excellent bond behavior between tendon grout and concrete. Primary corrosion protection is provided by the alkalinity of the grout and concrete.

Dimensions of Corrugated Metal Duct (Standard Sizes)

tendon type 0.5“	tendon type 0.6“	sheathing I.D.	sheathing O.D.
		in/mm	in/mm
5907	6805	2/50	2.15/54.6
5909	6807	2.375/60	2.6/66
5912	6809	3.12/80	3.31/84
5915	6812	3.52/90	3.7/94
5920	6815	3.63/93	3.82/97
5927	6819	4/100	4.19/106.3
5937	6827	4.6/117	4.78/121.4
	6837	5.26/134	5.45/138.4

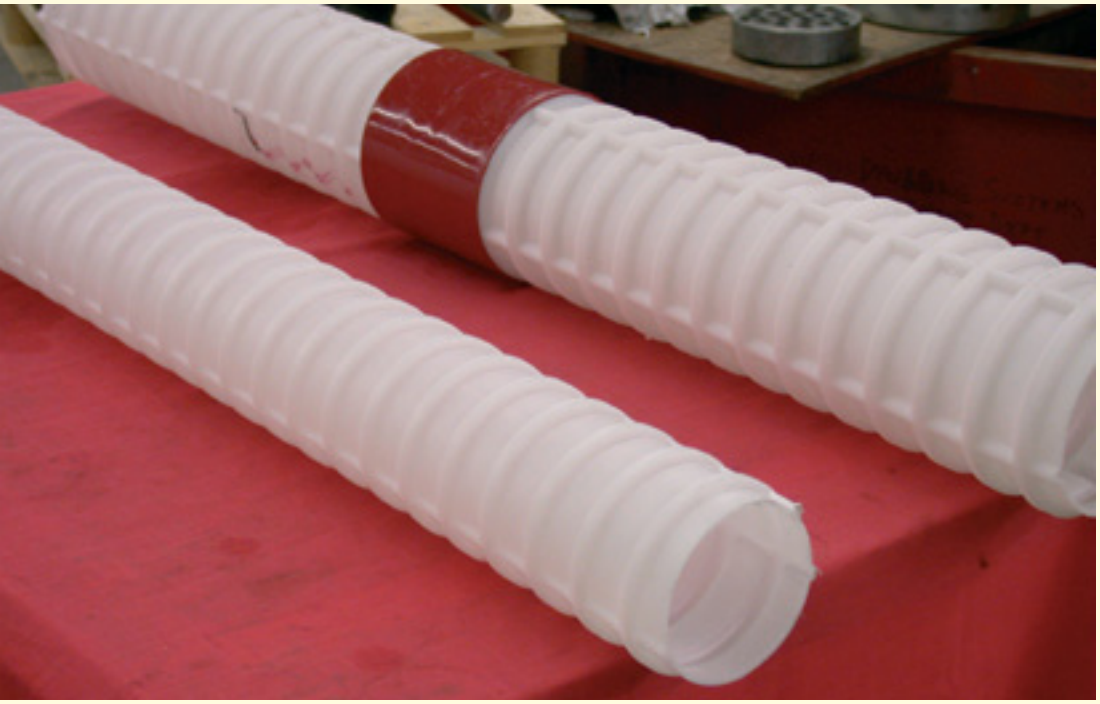


The tendon type number (e.g. 5904, 6807) is composed as follows: the first digit (5 or 6) identifies the nominal strand diameter in tenths of an inch, i.e. 0.5“ or 0.6“, the last two digits (..07) reference the number of used strands (= 7 strands). The second digit is an internal code.



tendon type 0.5“	tendon type 0.6“	min. center distances	support distances up to
		in/mm	ft/m
5904	6804	3.90/99	5.91/1.8
5905	6805	4.25/108	5.91/1.8
5907	6806	4.61/117	5.91/1.8
5909	6807	4.61/117	5.91/1.8
5912	6809	4.61/117	5.91/1.8
5915	6812	5.67/144	5.91/1.8
5920	6815	6.38/162	5.91/1.8
5927	6819	6.73/171	5.91/1.8
5937	6827	7.80/198	5.91/1.8
—	6837	9.25/235	5.91/1.8

PE/PP Round Duct



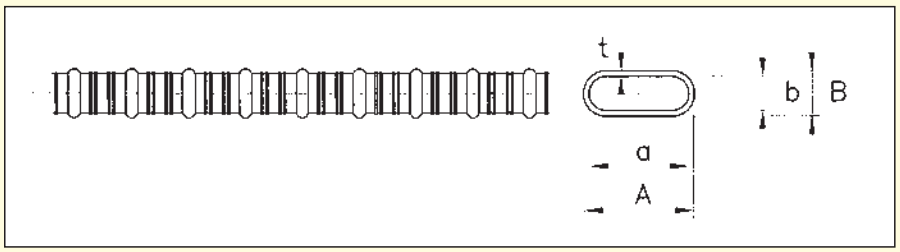
Thick-walled polyethylene / polypropylene (PPEX3) plastic ducts provide long-term secondary corrosion protection especially in aggressive environments such as waste water treatment plants, acid tanks or silos.

DYWIDAG-Systems International offers polyethylene/polypropylene (PPEX3) ducts in straight lengths up to 80 feet for all sizes. Standard shipping length is 40 feet. Longer lengths in coils are available for all sizes except 130 mm.

Dimensions of Round Corrugated PE/PP Duct (Standard Size)

tendon type	tendon type	sheathing		wall thickness
		I.D.	O.D.	
0.5“	0.6“	in/mm	in/mm	in/mm
5907	6805	2.32/59	2.874/73	.079/2
5909	6807	2.32/59	2.874/73	.079/2
5912	6809	2.99/76	3.58/91	.1/2.54
5915	6812	3.31/84	3.95/100	.1/2.54
5920	6815	3.93/100	4.53/115	.1/2.54
5927	6819	3.93/100	4.53/115	.1/2.54
5937	6827	4.55/115	5.36/136	.14/3.56
	6837	5.12/130	5.96/151	.14/3.56

Flat PE/PP Duct



type	tendon type	A	B	a	b	wall thickness
	0.6“	(in/mm)	(in/mm)	(in/mm)	(in/mm)	(in/mm)
flat duct	6804	3.55/90.2	1.55/39.5	3.15/80	1.14/29	.079/2

Multiplane Anchorage MA

The two-part multiplane anchorage is primarily used for longitudinal tendons in beams and bridges.

The wedge plate and compact conical anchor body with three load transfer planes introduces the prestressing force gradually into the concrete member.

The separation of anchor body and wedge plate makes it possible to insert the strand after casting the concrete. The wedge plate self-centers on the anchor body providing accurate installation as well as trouble-free stressing. The anchorage is also suitable for cryogenic application (LNG-tanks).

The six bolt hole pattern in the anchor body is designed to accept a permanent plastic cap. Multiple grout ports allow for post grout inspection.

System 100

System 100

stressing anchorage	dead end anchorage accessible	dead end anchorage not accessible	coupling	ultimate load [kips/kN] from	ultimate load [kips/kN] to
✔	✔	✔	✔	287/1,302	2,168/9,644

pocket former for each anchorage system on request

Plate Anchorage SD

The single unit plate anchorage is designed for slab structures as well as transverse tendons in bridges. Small edge and center distances allow for an economical anchorage layout in tight situations.

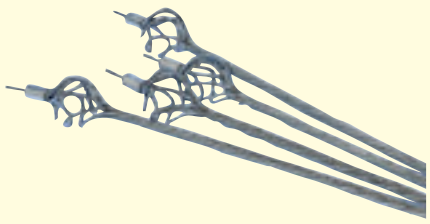
stressing anchorage	dead end anchorage accessible	dead end anchorage not accessible	coupling	ultimate load [kips/kN]
✔	✔	✔	N/A	1,040.8/234

pocket former for each anchorage system on request

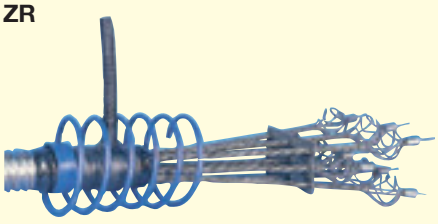
Bond Head Anchorage ZF/ZR

Primarily used with prefabricated tendons, it is also possible to fabricate this anchorage on site. The strand wires are plastically deformed to ensure safe load transfer up to ultimate capacity in the area of the bond head. Anchorage performance has been proven in static as well as in dynamic applications. Depending on the boundary conditions either a two-dimensional or a three-dimensional bond head anchorage pattern is available.

ZF



ZR



stressing anchorage	dead end anchorage accessible	dead end anchorage not accessible	coupling	ultimate load (0.5) [kips/kN] from	ultimate load (0.5) [kips/kN] to	ultimate load (0.6) [kips/kN] from	ultimate load (0.6) [kips/kN] to
–	–	✔	–	41.3/184	1,115/4,961	58.6/261	1,582/7,037

Loop Anchorage HV

Often used in large plate-shaped structures, walls, piers or LNG tanks. The 180° loop should be positioned in the center of the tendon to minimize movement of the strand within the loop during simultaneous two-end stressing.

stressing anchorage	dead end anchorage accessible	dead end anchorage not accessible	coupling	ultimate load [kips/kN] from	ultimate load [kips/kN] to
–	–	✔	–	82/372	1.169/5,301

Flat Anchorage FA

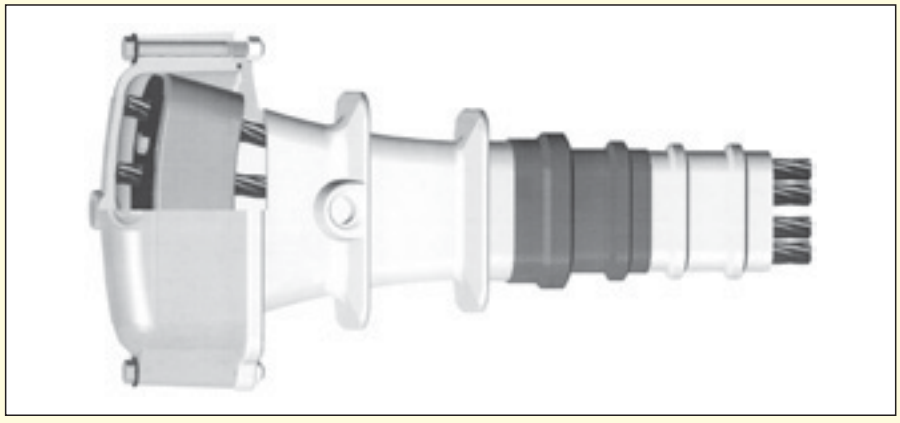
The 3-0.6“ and 4-0.6“ Flat Anchorage provides strands in one plane with a trumpet to deviate the strands into an oval duct. The Flat Anchorage is designed to be installed in thin members such as transverse post-tensioning of bridge decks and prestressed flat slabs.

stressing anchorage	dead end anchorage accessible	dead end anchorage not accessible	coupling	ultimate load [kips/kN] from	ultimate load [kips/kN] to
✔	✔	✔	–	175/782	234/1043

pocket former for each anchorage system on request

Flat Anchorage System 100

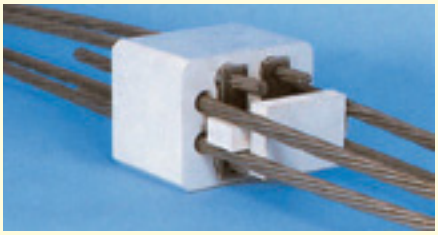
The two part multiplane anchorage is designed primarily for bridge transverse post-tensioning. The System 100 meets the Florida Department Of Transportation specifications regarding corrosion protection.



Coupler M/ME (Floating Anchorage Block)

Cylindrical structures (water tanks, digestor tanks, large pipes or dome shells) that require circumferential post-tensioning are the principal applications for the floating coupler M/ME. The tendon anchorage consists of an anchorage block with wedge holes on both sides to accept bare or greased and sheathed strands. The strands overlap within the block. The ring-tendon is very compact and requires a small pocket. Stressing is performed using conventional jacks and a curved jack nose.

M



ME

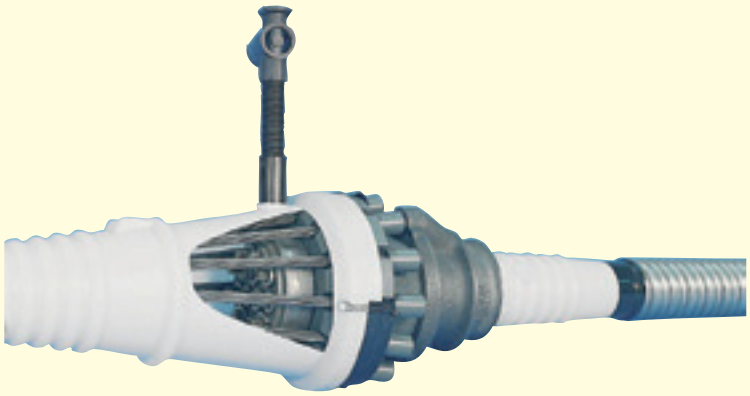
stressing anchorage	dead end anchorage accessible	dead end anchorage not accessible	coupling	ultimate load [kips/kN] from	ultimate load [kips/kN] to
✔	✔	–	–	62/279	738/3,348

pocket former for each anchorage system on request
M anchorage available in 2, 4, 6, 8 and 12-0.6 Versions

Coupler P

P Coupler consists of a multiplane anchorage body, a standard wedge plate and a coupler ring that accepts the continuing strands with swaged anchorages instead of wedges.

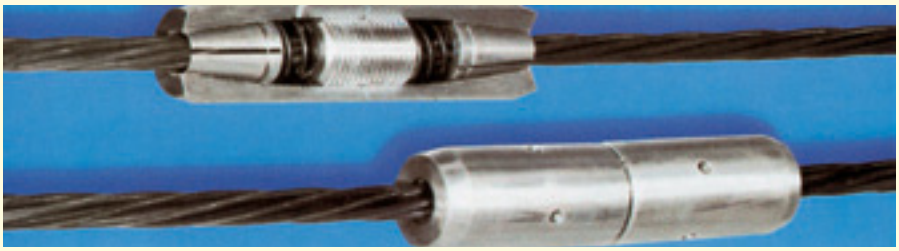
The Coupler P is available in 5, 9, 12, 15, 19 and 27-0.6 versions.



fixed coupler	floating coupler	ultimate load [kips/kN] from	ultimate load [kips/kN] to
✔	–	293/1303	1113/4953

Coupler D

The D Coupler is used to lengthen unstressed tendons in segmental bridge construction. The coupler consists of two spring-loaded wedges that connect two strands individually.



fixed coupler	floating coupler	ultimate load [kips/kN] from
–	✔	58.6/261

Available Anchorage Types

Tendon Type 59… (0.5“ system)

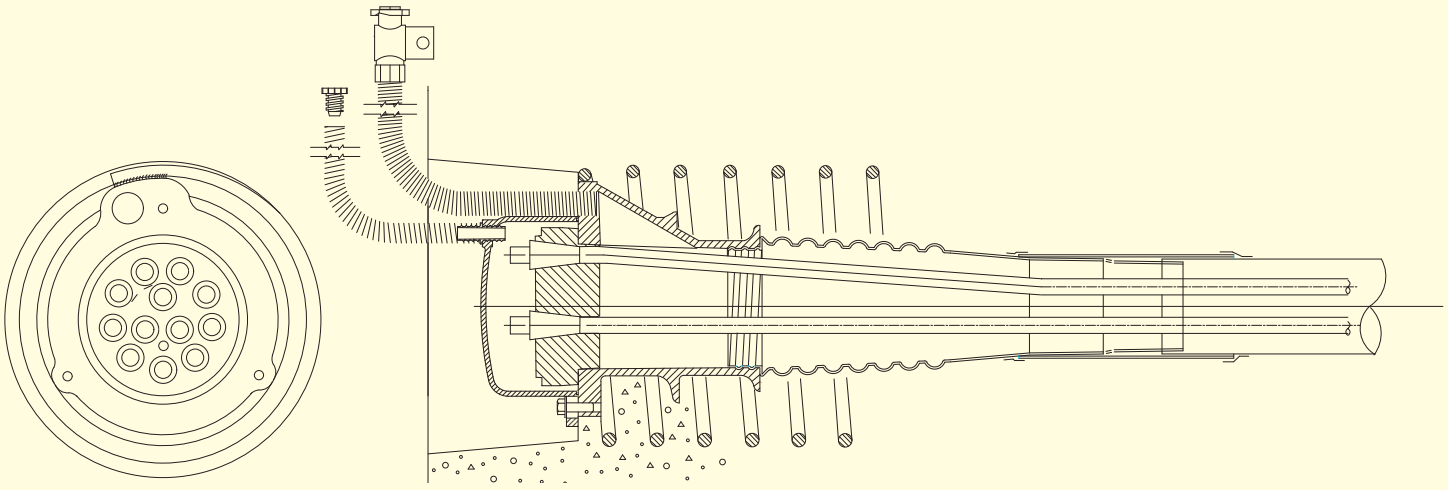
59...	01	02	03	04	05	06	07	08	09	12	15	20	27	37
Anchorage Type														
Multiplane Anchorage MA							●		●	●	●		●	●
Plate Anchorage SD				●										
Bond Head Anchorage ZF/ZR	●		●	●	●	●	●	●	●	●	●	●	●	
Loop Anchorage HV		●	●	●	●	●	●	●	●	●	●	●	●	●
Coupler D	●													

Other size tendons on request
Plate Anchor SD and Flat Anchor FA use 0.5“ Jumbo Wedge

Tendon Type 68… (0.6“ system)

68...	01	02	03	04	05	06	07	08	09	12	15	19	27	37
Anchorage Type														
Multiplane Anchorage MA					●		●		●	●	●	●	●	●
Plate Anchorage SD				●										
Mono Anchorage EV	●													
Bond Head Anchorage ZF/ZR	●		●	●	●	●	●		●	●	●	●	●	
Loop Anchorage HV		●	●	●	●	●	●		●	●	●	●	●	●
Flat Anchorage FA			●	●										
Coupler M and ME (Floating Anchorage)		●		●		●		●		●				
Coupler P					●				●	●	●	●	●	
Coupler D	●													

Other size tendons on request



System drawings are available on request for each type anchorage showing details and assembly instructions.
System 100 castings supplied with 6 bolt holes for installation of permanent plastic cap.

Installation

DYWIDAG-Systems International utilizes two different methods to insert strands into ducts. The installation method depends on the access conditions of the structure and the job site.

Uncoiling Cages

Method 1: Pushing

Pushing strands into the duct on the job site is very economical and can be done either before or after casting the concrete. The pushing equipment can be installed remotely and a flexible pipe connected to the insertion point. DSI strand pushers provide relatively high speeds of up to 25 ft/s (8 m/s) and require minimal operating personnel. These advantages make pushing the preferred method for strand installation.

Strand Pusher

Method 2: Pulling

To install strands while pulling them into the duct can be very efficient in special structures, for example where the loop anchorage is used. In most cases the entire bundle of strands is pulled through the duct using a winch with a steel cable.

Pre-Assembled Tendons

The prefabrication of tendons either in the shop or in the field can be very economical when the tendons are short and the location of the job site is close. Special uncoilers and hydraulic winches are usually required to properly install the tendons in the structure.

Stressing

DYWIDAG has developed a series of jacks and hydraulic pumps in order to efficiently and economically stress its tendons. Versatility is provided by changing devices that make one unit adaptable for many different tendon sizes. DYWIDAG jacks have capacities ranging from 56/250 kips/kN up to 2,191/9,750 kips/kN.

Jack HoZ 4,000

DYWIDAG jacks are highly sophisticated, but still easy to operate. They employ inner tube bundles with automatic gripping devices that guide the strand safely through the inside of the jack. This feature makes it possible to control the stressing operation with the highest degree of reliability. Minimal wedge seating losses can be achieved with the power seating option. Power seating hydraulically seats the wedges with a predetermined load, individually and simultaneously, rather than relying simply on friction seating. DYWIDAG jacks also make it possible to overstress and release a tendon to compensate for friction losses and maximize the stress level over the tendon length.

Tensa 4,800

Every jack has a pressure relief valve that safely limits hydraulic pressure to prevent overload. To verify the stressing operation a gauge port is provided directly on the jack.

Stressed tendons can be safely destressed by employing special wedges and a special jack configuration. Hydraulic pumps are generally equipped with a convenient remote control device. Further information concerning the equipment is provided on page 19 to 21.

Hydraulic pump

Some important notes concerning the safe handling of high strength strand for prestressed concrete:

1. Do not damage surface of the strand.
2. Do not weld or burn so that sparks or hot slag will touch any portion of the strand which will be under stress.
3. Do not use any part of the strand as a ground connection for welding.
4. Do not use strand that has been kinked or contains a sharp bend.

Disregard of these instructions may cause failure of material during stressing.

Grouting

Mixing and pumping equipment

The durability of post-tensioned construction depends mainly on the success of the grouting operation. The hardened cement grout provides bond between concrete and prestressed steel as well as primary long-term corrosion protection for the prestressing steel.

DYWIDAG has developed grouting methods based on thixotropic and highly plasticized grout and utilizes durable grouting equipment. Advanced methods such as pressure grouting, post-grouting and vacuum grouting are all results of many years of development.

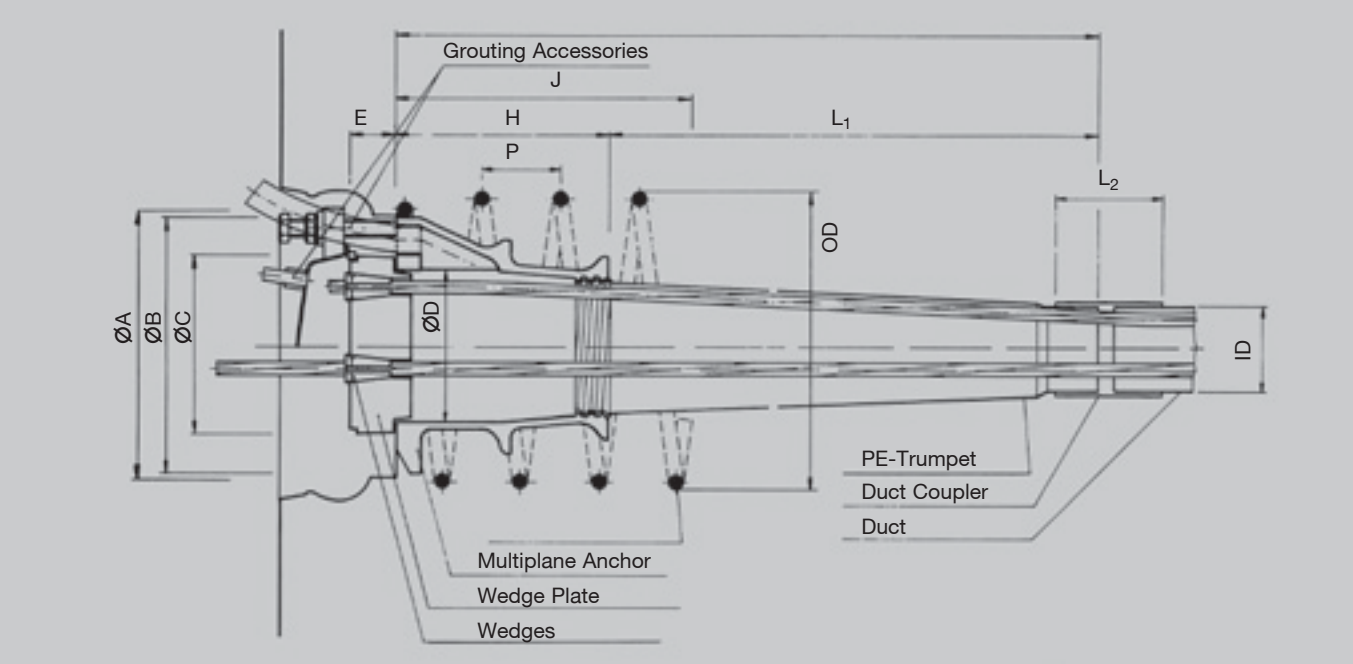
Grouting is always done from a low-point of the tendon. This can be one of the anchorages where a grout cap with grout hose is the port for the grout or along the tendon utilizing an intermediate grout saddle. All grouting components are threaded for easy, fast and positive connection.

Venting operation

Mixing and pumping

Vacuum grouting

Multiplane Anchorage MA

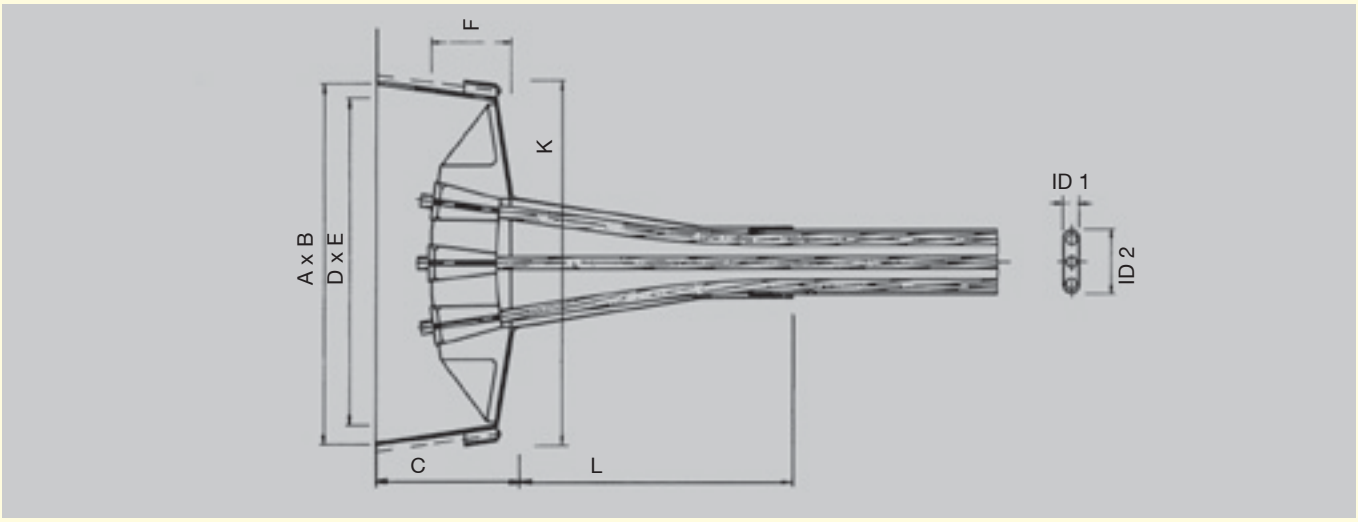


▶ Technical Data

Anchorage Size		5-0.6“ or 7-0.5“	7-0.6“ or 9-0.5“	9-0.6“ or 12-0.5“	12-0.6“ or 15-0.5“	15-0.6“ or 20-0.5“	19-0.6“ or 27-0.5“	27-0.6“ or 37-0.5“	37-0.6“
Min. Block-out Dia.	A	7 \ 179	8 \ 203	9 \ 229	10 \ 254	11 \ 279	12 \ 305	13-1/2 \ 343	16 \ 407
Transition Length		12-3/8 \ 314	13-7/16 \ 341	15-3/4 \ 400	20 \ 508	22-5/8 \ 575	25-3/16 \ 640	27-5/8 \ 702	35 \ 890
Anchor Dia.	B	5-15/16 \ 150	6-11/16 \ 170	7-1/2 \ 190	8-5/8 \ 220	9-7/8 \ 250	11 \ 280	12-3/8 \ 315	14-1/8 \ 360
	D	3-9/16 \ 90	3-7/8 \ 98	4-7/16 \ 113	5-1/16 \ 128	5-13/16 \ 148	6-3/8 \ 162	7-1/2 \ 190	8-1/2 \ 220
	H	3-9/16 \ 90	3-15/16 \ 100	4-15/16 \ 125	7-1/16 \ 180	7-7/8 \ 200	8-5/8 \ 220	9-7/16 \ 240	12-1/2 \ 320
Wedge Plate	C	5-1/8 \ 130	5-1/8 \ 130	5 1/2 \ 140	6-5/16 \ 160	7-1/16 \ 180	7-7/8 \ 200	9-7/16 \ 240	10-2/3 \ 270
	E	2 \ 50	1-9/16 \ 40	1-11/16 \ 43	1-11/16 \ 43	2 \ 50	2-3/16 \ 55	2-15/16 \ 75	3-1/2 \ 90
Trumpet	L1	8-7/8 \ 225	9-1/2 \ 241	10-13/16 \ 275	12-7/8 \ 327	14-3/4 \ 375	16-1/2 \ 419	18-1/8 \ 460	22-1/2 \ 600
Rebar Spiral*	Size	# 4 \ 15M	# 4 \ 15M	# 4 \ 15M	# 5 \ 15M	# 5 \ 15M	# 5 \ 15M	# 6 \ 20M	# 7 \ 22M
	Grade 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa	60 KSI \ 400 MPa
	Pitch	1-7/8 \ 50	1-7/8 \ 50	1-7/8 \ 50	2-1/4 \ 55	1-7/8 \ 50	1-7/8 \ 50	2-1/4 \ 55	2-3/8 \ 60
	J	10 \ 255	10-1/2 \ 265	10-5/8 \ 270	14 \ 355	14-3/4 \ 365	15 \ 380	16-5/8 \ 420	18 \ 460
	OD	7-3/4 \ 190	9 \ 230	9-1/2 \ 240	11-1/4 \ 285	12-1/2 \ 315	14-1/2 \ 365	17 \ 430	22 \ 560
Duct	ID	2 \ 50	2-3/8 \ 60	3 \ 75	3-3/8 \ 85	3-3/4 \ 95	4 \ 100	4-1/2 \ 115	5-1/8 \ 130
Duct Coupler	L2	8 \ 200	8 \ 200	8 \ 200	8 \ 200	8 \ 200	8 \ 200	8 \ 200	12 \ 300
Grout Requirements	gal/ft \ l/m	0.12 \ 1.5	0.17 \ 2.1	0.28 \ 3.46	0.35 \ 4.39	0.44 \ 5.48	0.47 \ 5.80	0.58 \ 7.25	0.72 \ 8.90

* Spiral required in local anchor zone
All dimensions are nominal and are expressed in inch \ mm.

Flat Anchorage FA / Plate Anchorage SD



Flat Anchorage FA

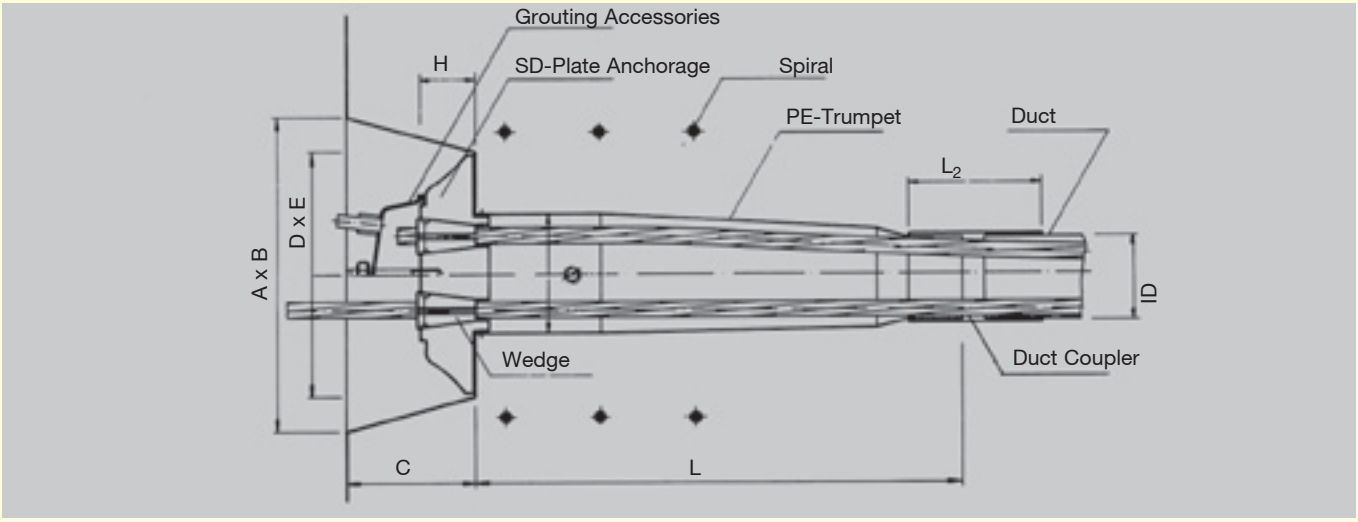


Plate Anchorage SD

▶ Technical Data

Flat Anchorage FA

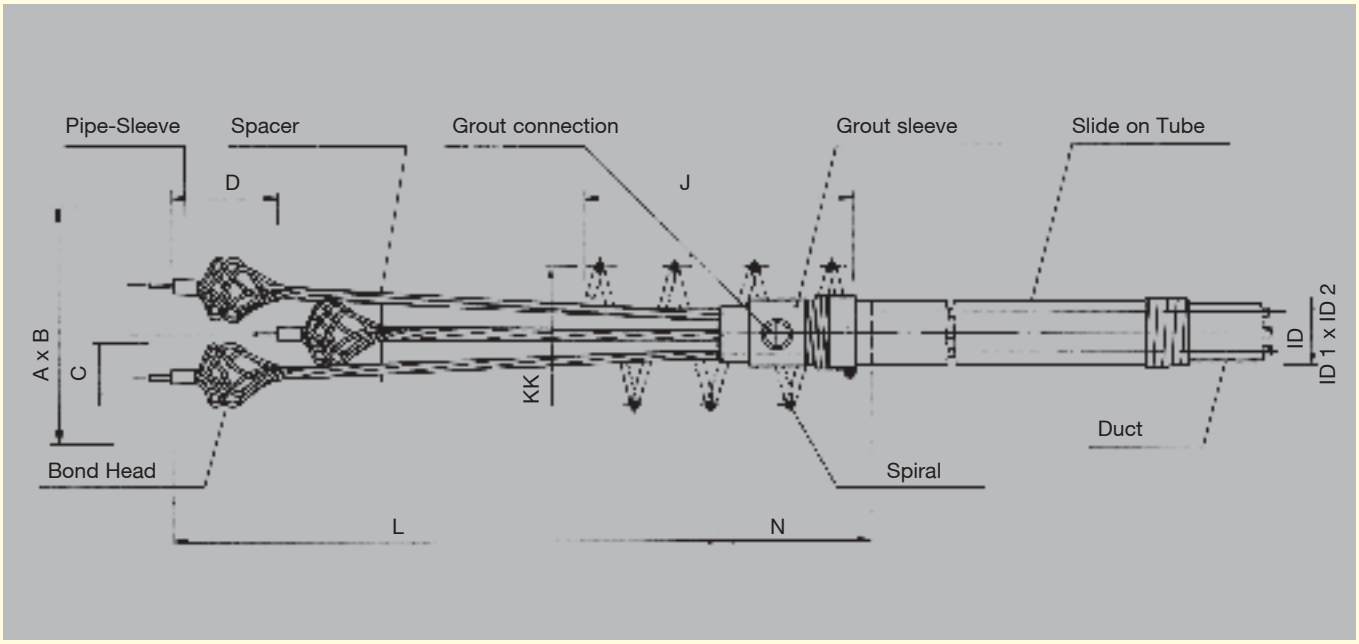
Tendon Size		3-0.6“ or 4-0.5“	4-0.6“ or 5-0.5“
Flat	D	10\255	13\330
Anchorage	E	4\100	4\100
	F	2-1/4\57	2-1/4\57
Transition	K	12-1/4\310	–
	L	4-1/2 \ 115	8-5/8 \ 220
Pocket	A	10-3/4\275	13-3/4\350
Former	B	4-1/2\115	4-7/8\124
	C	5-1/2\140	5-7/8\148
Duct	ID1	1\25	1\25
	ID2	3\75	3\75

Combination Plate Anchorage SD

Tendon Size		3-0.6“ or 4-0.5“	4-0.6“ or 5-0.5“	5-0.6“ or 7-0.5“	6-0.6“ or 8-0.5“	7-0.6“ or 9-0.5“
Combin.	D	4-15/16\125	5-5/16\135	5-7/8\150	6-1/2\165	6-11/16\170
Plate	E	5-1/2\140	6-5/16\160	7-1/16\180	8-1/16\205	8-1/2\215
	H	1-5/8\41	1-5/8\41	1-9/16\40	1-3/4\44	1-3/4\44
Transition	∅	2-9/16\65	2-15/16\75	3-3/8\85	3-3/4\95	3-3/4\95
	L	11-3/8 \ 290	10-7/16\265	14\355	15-15/16\405	15-15/16\405
Pocket	A	6-1/2\165	6-1/2\165	7-1/16\180	7-7/8\200	7-7/8\200
Former	B	7-5/16\185	7-5/16\185	8-1/4\210	9-7/16\240	9-7/16\240
	C	3-15/16\100	3-15/16\100	3-15/16\100	4-5/16\110	4-5/16\110
Duct	ID	1-9/16\40	1-13/16\46	2-1/16\52	2-7/16\62	2-7/16\62
	L2	8\200	8\200	8\200	8\200	8\200

All dimensions are nominal and are expressed in inch \ mm.

Bond Head Anchorage Z



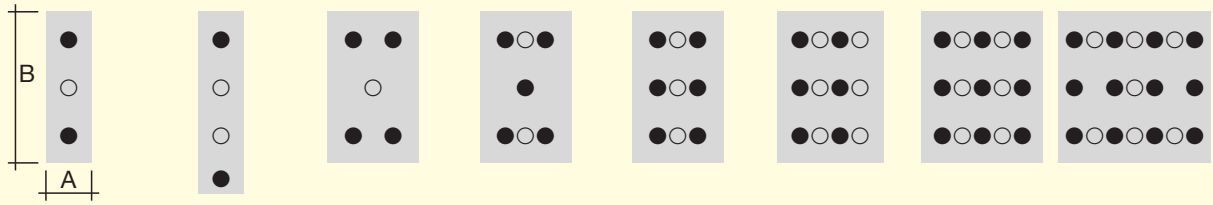
▶ Technical Data

Tendon Size

Strand Arrangement

● long

○ short

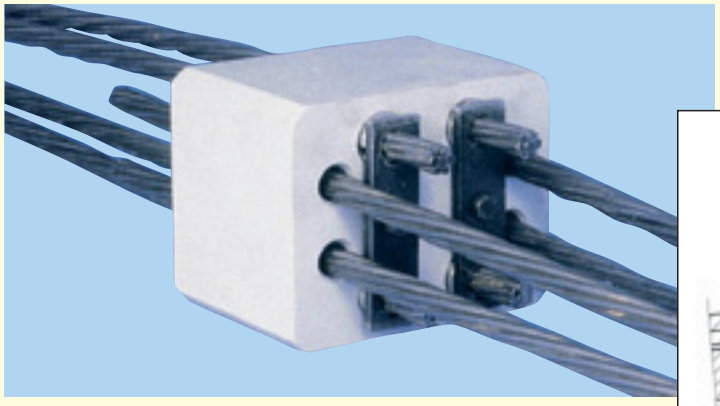


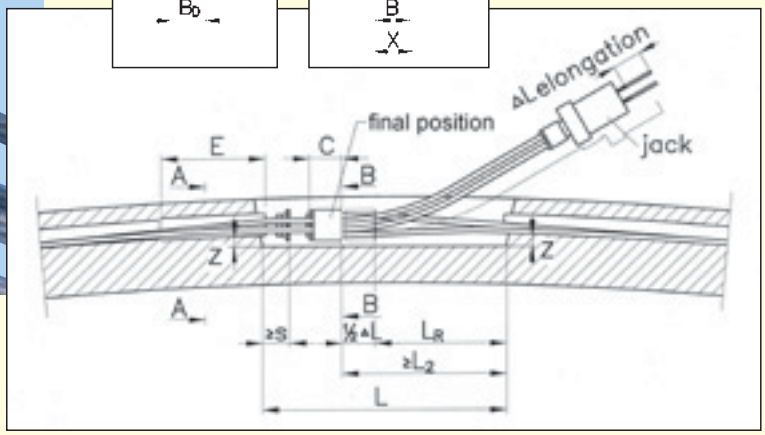
Tendon Size		3-0.6“	4-0.6“	5-0.6“	7-0.6“	9-0.6“	12-0.6“	15-0.6“	19-0.6“
Anchorage	A	7 \ 178	7 \ 178	11 \ 280	11 \ 280	15 \ 380	15 \ 380	15 \ 380	15 \ 380
	B	11 \ 280	13 \ 330	11 \ 280	11 \ 280	11 \ 280	13 \ 330	15 \ 380	19 \ 483
	C	3 \ 75	3 \ 75	3 \ 75	3 \ 75	3 \ 75	3 \ 75	3 \ 75	3 \ 75
	D	6 \ 150	6 \ 150	6 \ 150	6 \ 150	6 \ 150	6 \ 150	6 \ 150	6 \ 150
	L	40 \ 1015	40 \ 1015	40 \ 1015	40 \ 1015	40 \ 1015	40 \ 1015	40 \ 1015	40 \ 1015
Grout Sleeve	N	8-1/4 \ 210	9 \ 230	9 \ 230	9 \ 230	9 \ 230	9 \ 230	9 \ 230	9 \ 230
Duct-Round	ID	–	–	2 \ 50	2-3/8 \ 60	3 \ 75	3-1/2 \ 90	3-3/4 \ 95	4 \ 100
Duct-Eliptical	ID1	1 \ 25	1 \ 25	–	–	–	–	–	–
	ID2	2 \ 50	3 \ 75	–	–	–	–	–	–
Spiral	K	4-1/8 \ 105	7-7/8 \ 200	7-7/8 \ 200	7-7/8 \ 200	7-7/8 \ 200	7-7/8 \ 200	7-7/8 \ 200	7-7/8 \ 200
	J	10 \ 255	10 \ 255	10 \ 255	10 \ 255	10 \ 255	10 \ 255	10 \ 255	12 \ 305

Lightweight hydraulic equipment is used for fabrication of bond heads. All dimensions are nominal and are expressed in inch\mm.

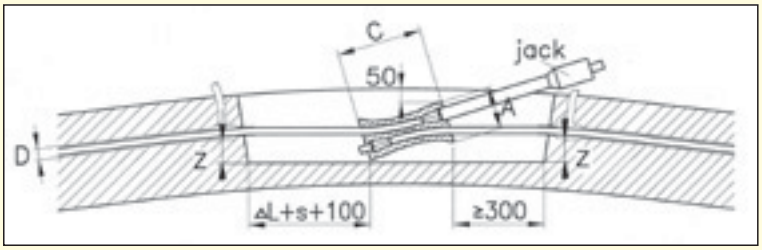
Coupler M/ME (Floating Anchorage Block)

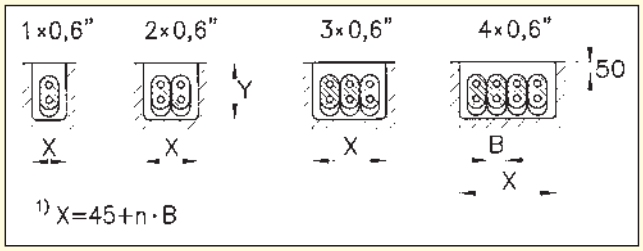
Coupler M





Coupler ME



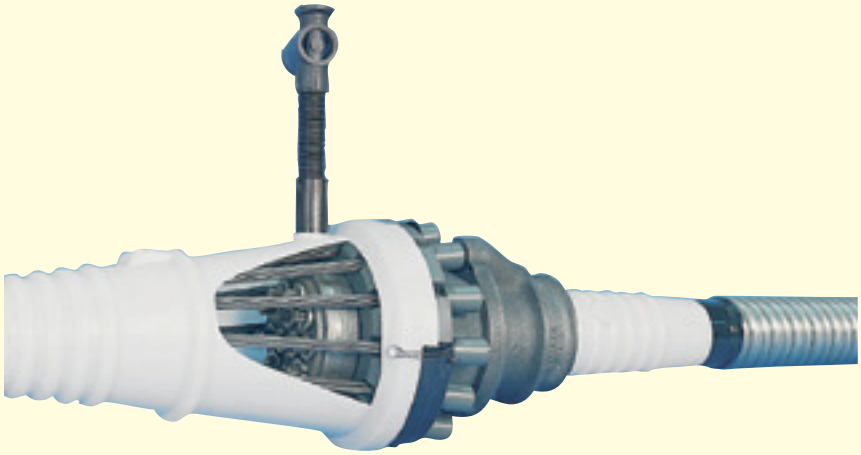


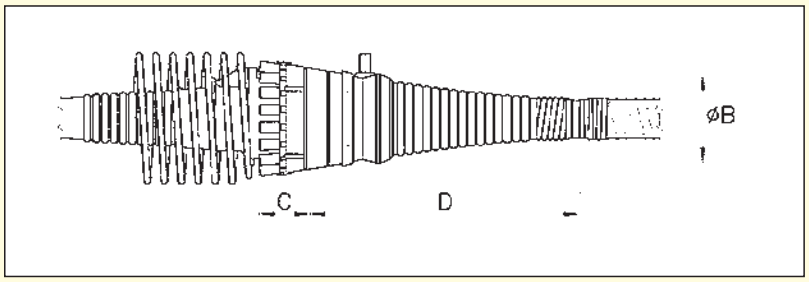
▶ Technical Data

Tendon Size		2-0.6“	4-0.6“	6-0.6“	8-0.6“	12-0.6“
Block-Out Cross Section for 2“ [50 mm] Concrete Cover	X	5-1/8 \ 130	7-1/16 \ 180	7-1/16 \ 180	9 \ 230	9 \ 230
	Y	6-1/8 \ 155	7-11/16 \ 195	7-11/16 \ 195	7-11/16 \ 195	9-1/4 \ 235
	A	3-1/2 \ 90	5-1/8 \ 130	5-1/8 \ 130	5-1/8 \ 130	6-5/8 \ 168
	B	4-1/8 \ 105	6-1/4 \ 160	6-1/4 \ 160	8-1/4 \ 210	8-1/4 \ 210
	C	4-3/4 \ 120	4-3/4 \ 120	4-3/4 \ 120	4-3/4 \ 120	4-3/4 \ 120
Duct	E	7-7/8 \ 200	25-5/8 \ 650	25-5/8 \ 650	41-3/8 \ 1050	45-1/4 \ 1150
– Rectangular	A_D	2-3/8 \ 60	2-3/8 \ 60	2-3/4 \ 70	2-3/4 \ 70	2-3/4 \ 70
– Rectangular	B_D	2-3/4 \ 70	5-1/8 \ 130	5-1/8 \ 130	6-5/8 \ 170	6-5/8 \ 170
– Round	D	1-3/4 \ 45	2-1/8 \ 55	2-5/8 \ 65	3 \ 75	3-1/8 \ 80
– Min. Distance	Z	2 \ 50	2-3/4 \ 70	2-3/4 \ 70	2-3/4 \ 70	3-1/2 \ 90
Min. Required Distance after Stressing	L_2	17-3/4 \ 450	27-1/2 \ 700	27-1/2 \ 700	53-1/8 \ 1350	59 \ 1500
Space Required for Stressing Jack Nose	L_R	21-5/8 \ 550	23-5/8 \ 600	23-5/8 \ 600	23-5/8 \ 600	27-1/2 \ 700
Block-Out Length	$L = s + 11\text{-}1/4“ (285 mm) + L_2$			If $L_R \leq L_2 - 1/2\ \Delta L$		
	$L = s + 1/2\ \Delta L + 11\text{-}1/4“ (285mm) + L_s$			If $L_R \geq L_2 - 1/2\ \Delta L$		
	Where s = 0.2 x 1/2 ΔL, but 5“ (125 mm) min.					
	ΔL is Elongation					

All dimensions are nominal and expressed in inch\mm.

Coupler P





DYWIDAG Coupler “P” utilizes a standard wedge plate and a slotted coupling ring bearing on the multi-plane anchorage. An extruded grip is hydraulically installed on the ends of the coupled strands and the strands are placed in the slots of the coupling ring. This system provides a simple and inexpensive solution for coupling large strand tendons.

▶ Technical Data

type 0.6“	∅ A (in/mm)	∅ B (in/mm)	C (in/mm)	D (in/mm)
6805	6.93/176	4.53/115	5.2/132	20/510
6809	9.29/236	8.07/205	5.35/136	22.44/570
6812	10.24/260	8.86/225	5.71/145	29.72/755
6815	11.42/290	9.84/250	5.91/150	29.72/755
6819	12/305	10.43/265	6.1/155	34.65/880
6827	14.37/365	12.6/320	6.69/170	35.63/905

▶ Details of the Coupler Zone

type 0.6“	center distances of anchorages in/mm	length of space for installation in/mm
6805	11.81/300	78.75/2000
6809	14.17/360	78.75/2000
6812	15.35/390	78.75/2000
6815	16.54/420	78.75/2000
6819	18.90/480	78.75/2000
6827	22.83/580	78.75/2000

Equipment Overview

Hydraulic Jacks

Monostrand Jack

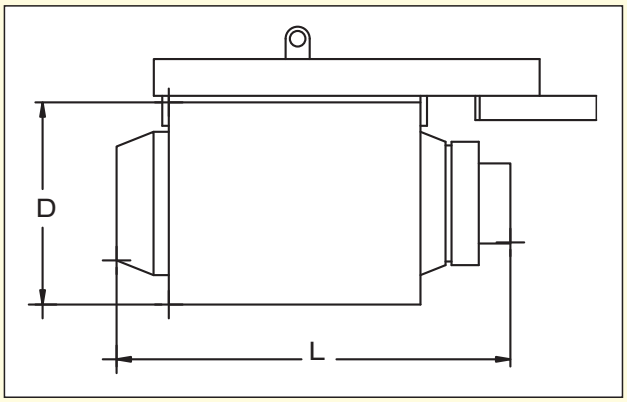
Tensa 4,800 / 6,800 / 8,600

HoZ 3,000 / 4,000

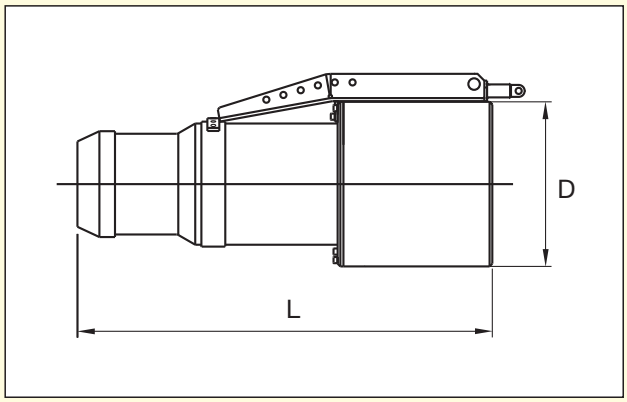
	59 .. (0.5“)													
jack type	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**12**	**15**	**19**	**27**	**37**
Mono 0.6	●													
HoZ 950		●	●	●	●									
HoZ 1,700						●	●	●	●					
HoZ 3,000										●	●			
HoZ 4,000												●	●	
Tensa 260														
Tensa 3,000														
Tensa 4,800														
Tensa 6,800														●
Tensa 8,600														

	68 .. (0.6“)													
jack type	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**12**	**15**	**19**	**27**	**37**
Mono 0.6	●													
HoZ 950		●	●	●										
HoZ 1,700					●	●	●							
HoZ 3,000								●	●	●				
HoZ 4,000											●	●		
Tensa 260								●	●	●				
Tensa 3,000								●	●	●				
Tensa 4,800											●	●		
Tensa 6,800													●	
Tensa 8,600														●

Tensa Style



HoZ Style



▶ Technical Data

jack type[1]	length L[3]	diameter D	stroke	piston area	capacity[2]	weight
	(in/mm)	(in/mm)	(in/mm)	(in^2/cm^2)	(kip/kN)	(lbs/kg)
Mono 0.6	21.5/546	n/a	8.5/213	7.95/51.3	60/267	52/24
HoZ 950	24.45/621	8/203	3.94/100	25.1/162	218/972	144/65
HoZ 1,700	31.6/803	11/280	5.9/150	46.26/298.45	392/1,745	354/160
HoZ 3,000	44.76/1,137	15.16/385	9.84/250	78.9/509	687/3,054	884/400
HoZ 4,000	50/1,271	18.98/482	9.84/250	138.7/894.6	945/4,204	1,326/600
Tensa 2,600	30.9[3]/785	14.57/370	9.84/250	85.2/549.8	572/2,546	729/330
Tensa 3,000	30.9[3]/785	14.57/370	9.84/250	85.2/549.8	680/3,024	782/354
Tensa 4,800	39.6[3]/1,005	18.5/470	11.81/300	135.86/876.5	1,083/4,820	1,432/648
Tensa 6,800	45.3[3]/1,150	22/560	11.81/300	191.7/1,237	1,529/6,803	2,619/1,185
Tensa 8,600	46[3]/1,170	26.8/680	11.81/300	274.7/1,772.5	2,191.4/9,748	3,912/1,770

NOTE:
Detailed operating and safety instructions are provided with all stressing and grouting units. Read and understand these instructions before operating equipment.

1) power seating included
2) without friction
3) retracted position

Equipment Overview

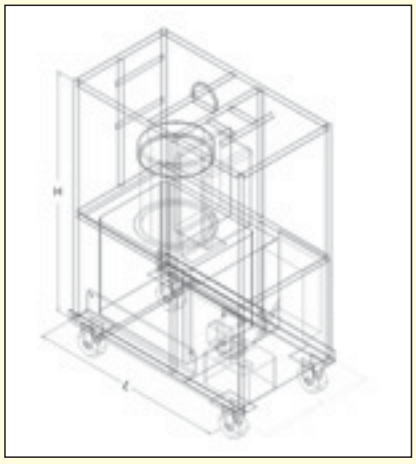
Hydraulic Pumps

PE 55

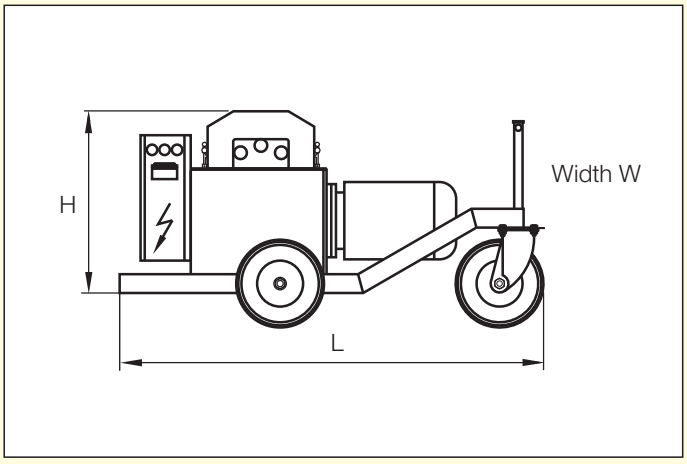
PE 4000

R 11.2 - 11.2/210

jacks	0.6 mono	HoZ 950	HoZ 1,700	HoZ 3,000 Tensa 3,000/260	HoZ 4,000 Tensa 4,800	Tensa 6,800	Tensa 8,600
Pumps							
PE55	●	●					
PE4000/PE55			●	●	●		
R11.2						●	●



PE 4000



R 11.2

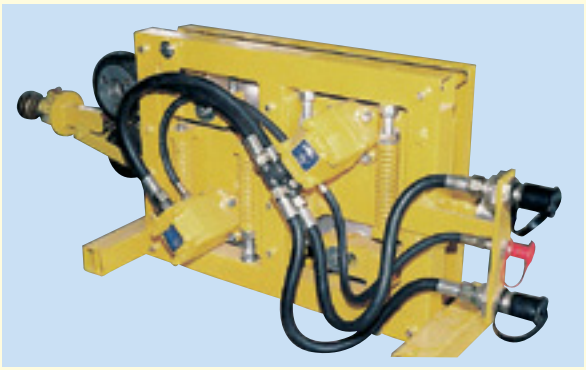
▶ Technical Data

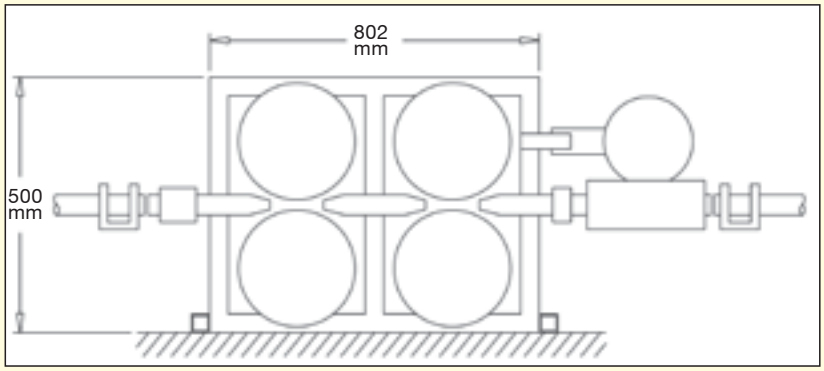
Pumps	operating pressure psi/MPa	capacity V/min Gpm/Lpm	eff. oil amount G/L	weight lbs/kg	dimensions LxWxH in	dimensions LxWxH mm	amp draw
PE55	10,000/69	.3[1]/1.14	2/7.57	65/29.4	11.5/9.5/18.25	292/241/464	25[2]
PE4000	10,000/69	1.95[1]/7.37	20/75.7	492/223	25/24/36.5	635/610/927	17[3]
R11.2	7,970/55	5.9/22.4	44.9/170	1,590/720	78.75/31.5/51.2	2,000/800/1,300	46[3]

1) At operating pressure
2) At 10,000 psi, 115 Volt
3) At 460 Volt

Pushing and Grouting Equipment

Pushing Equipment



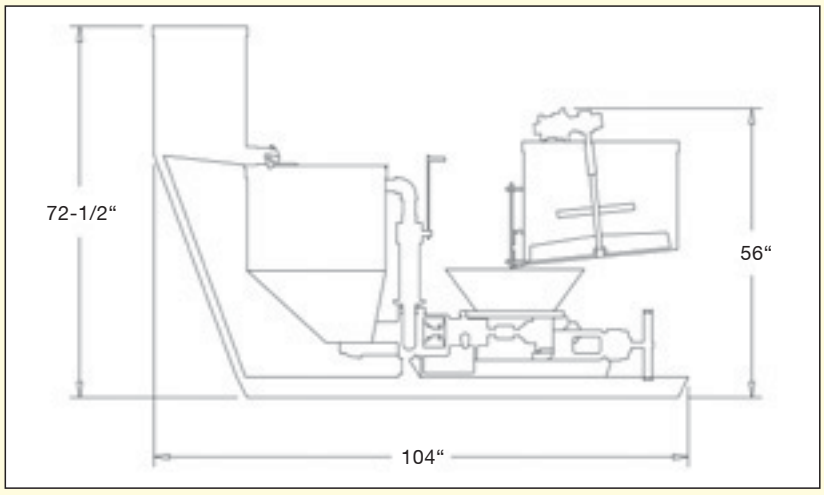


ESG 8 - 1

type	pushing force	pushing speed	weight	dimensions L x W x H	hydraulic pumps	amp draw
	kips	ft/s	lbs	in	-	
	kN	m/s	kg	mm		
ESG 8 - 1	0.88	20	309	55/13.8/20	ZP 57*	44
	3.9	6.1	140	1,400/350/510		

* Can also use R35 pump.

Grouting Equipment
(mixing and pumping)



CG600 Colloidal

grouting equipment	max injection pressure	capacity	weight	dimensions L x W x H
	psi	gpm	pounds	in
	MPa	l/h	kg	mm
CG600 Colloidal				
— with Moyno pumps	250	20	1,100	90 x 37 x 63
	1.7	4542	500	2286 x 940 x 1600
— with Piston Pump (1,000 psi)	1,000	20	1,725	90 x 37 x 63
	6.9	4542	784	2286 x 940 x 1600

Note: Air pressure required to operate is 280 cfm@100 psi

DYWIDAG BARS

The components of the DYWIDAG Bar System are manufactured in the United States exclusively by DYWIDAG-Systems International. Used worldwide since 1965, the system provides a simple, rugged method of efficiently applying prestress force to a wide variety of structural applications including post-tensioned concrete, as well as rock and soil anchor systems.

Available in 1“ (26.5 mm), 1 1/4“ (32 mm) and 1 3/8“ (36 mm) THREADBARS® are hot rolled and proof stressed alloy steel conforming to ASTM A722 CAN/CSA (G279-M1982). The 1 3/4“ (46 mm) and 2 1/2“ (65 mm) nominal diameter bar is cold drawn quenched and tempered alloy steel which after threading also conforms to the strength properties specified in A722.

The DYWIDAG THREADBAR® prestressing steel has a continuous rolled-in pattern of thread-like deformations along its entire length. More durable than machined threads, the deformations allow anchorages and couplers to thread onto the THREADBAR® at any point. The 1 3/4“ (46mm) and 2 1/2“ (65mm) bar can be cold threaded for its entire length or if enhanced bond is not required the bars can be supplied with threaded ends only.

The strength of the DYWIDAG anchorages and couplers exceeds the requirements of ACI 318 and the PTI Acceptance Standards for Post-Tensioning Systems.

Bars may also be galvanized, but will lose about 5% of their strength. Epoxy coating is the preferred method.

Test reports are available for the principal components of the system.

Conforming to the requirements of ASTM A615, the deformations develop an effective bond with cement or resin grout. The continuous thread simplifies stressing. Lift-off readings may be taken at any time prior to grouting and the prestress force increased or decreased as required without causing any damage.

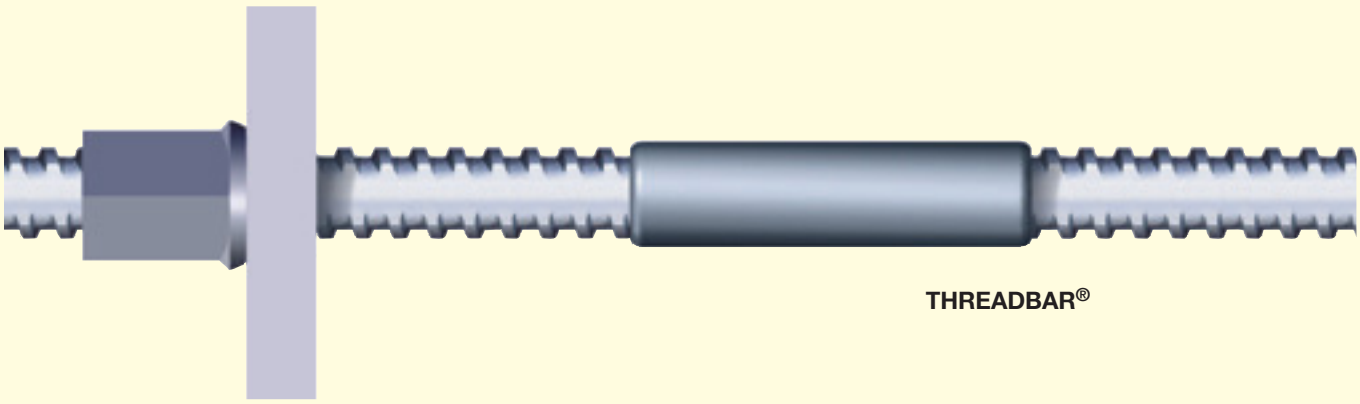
The DYWIDAG Bar System is primarily used for grouted construction. In addition they are sometimes used as external tendons with various types of corrosion protection.

All system components are designed to be fully integrated for quick and simple field assembly. Duct, duct transitions, grout sleeves and grout tubes all feature thread type connections.

Tendon duct can be metal or plastic. Galvanized or epoxy coated accessories that thread over the coated bar are available.

Placing DYWIDAG THREADBAR® anchorages is simplified by the use of reusable plastic pocket formers. Used at each stressing end, the truncated, cone-shaped pocket former can extend through, or butt up against the form bulkhead.

Threadbars are available in mill lengths to 60‘ (18.3 m), and may be cut to specified lengths before shipment to the job site. Where circumstances warrant, the threadbars may be shipped to the job site in mill lengths for field cutting with a portable friction saw or coupled to extend a previously stressed bar. Cold threaded 1 3/4“ (46 mm) and 2 1/2“ (65 mm) diameter are available in lengths up to 45 feet.



THREADBAR®

Prestressing Bar Properties

Nominal Bar Diameter (in.) (mm)	Ultimate Stress f_{pu} (ksi) (Mpa)	Cross Section Area A_{ps} ($in.^2$) (mm^2)	Ultimate Strength f_{pu} Aps (kips) (kN)	Prestressing Force (kips)(kN) 0.8 f_{pu} A_{ps}	0.7 f_{pu} A_{ps}	0.6 f_{pu} A_{ps}	Weight (lbs./ft.) (kg/m)	Minimum* Elastic Bending Radius (ft.) (m)	Maximum Bar Diameter (in) (mm)
1 in. 26 mm	150 1,030	0.85 548	127.5 567	102.0 454	89.3 397	76.5 340	3.01 4.48	52 15.9	1.20 30.5
$1^1/_4$ in. 32 mm	150 1,030	1.25 806	187.5 834	150.0 662	131.3 584	112.5 500	4.39 6.54	64 19.5	1.46 37.1
$1^3/_8$ in. 36 mm	150 1,030	1.58 1,018	237.0 1055	189.6 839	165.9 738	142.2 633	5.56 8.28	72 22.0	1.63 41.4
$1^3/_4$ in. 46 mm	150 1,030	2.62 1,690	400 1,779	320 1,423	280 1,245	240 1,068	9.22 13.72	92 28.0	2.00 51.0
$2^1/_2$ in. 66 mm	150 1,030	5.16 3,331	774 3,442	624 2,753	546 2,409	4,618 2,065	18.2 27.1	— —	2.79 70.9

* Prebent bars are required for radii less than the minimum elastic radius
** Grade 160 bar may be available on special request

Steel Stress Levels

DYWIDAG bars may be stressed to the allowable limits of ACI 318.The maximum jacking stress (temporary) shall not exceed 0.80 f_{pu}, and the transfer stress (lockoff) shall not exceed 0.70 f_{pu}.

ACI 318 does not stipulate the magnitude of prestress losses or the maximum final effective (working) prestress level.

Prestress losses due to shrinkage, elastic shortening and creep of concrete, as well as steel relaxation and friction must be considered.

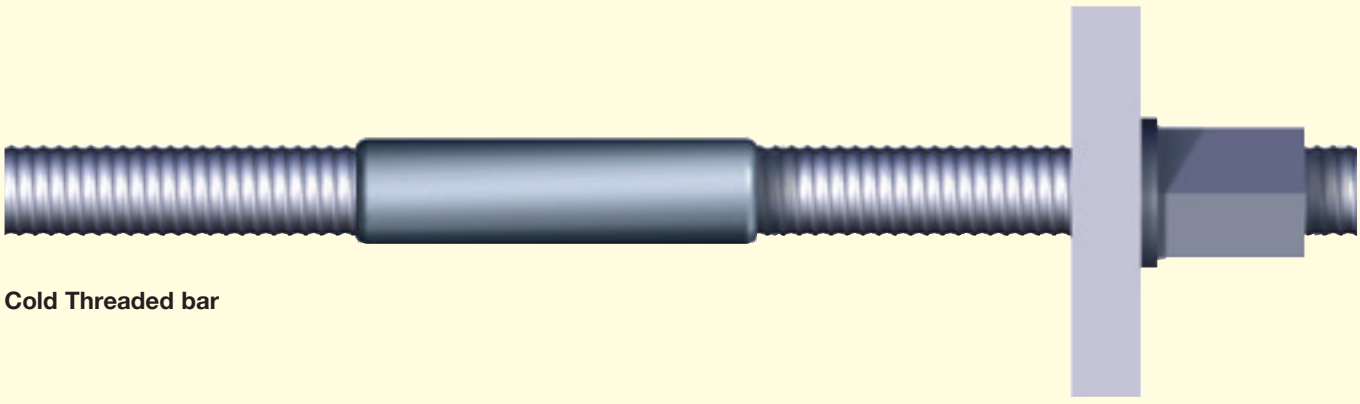
The final effective (working) prestress level depends on the specific application. In the absence of a detailed analysis of the structural system, 0.60 f_{pu} may be used as an approximation of the effective (working) prestress level.

Actual long term loss calculations require structural design information not normally present on contract documents.

Some important notes concerning the safe handling of high strength steel for prestressed concrete:

1. Do not damage surface of bar.
2. Do not weld or burn so that sparks or hot slag will touch any portion of bar which will be under stress.
3. Do not use any part of bar as a ground connection for welding.
4. Do not use bar that has been kinked or contains a sharp bend.

Disregard of these instructions may cause failure of material during stressing.

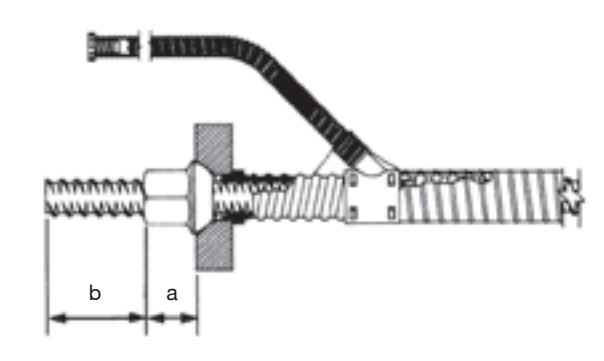


Cold Threaded bar

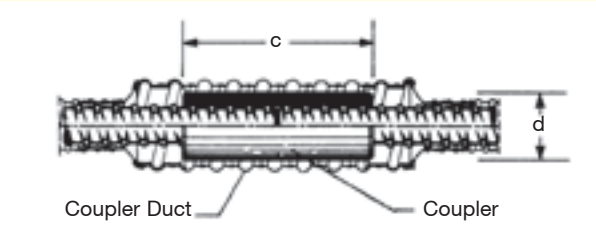
THREADBAR® Accessory Dimensions

Anchorage Details								
Bar Diameter	1“	26 mm	1-1/4“	32 mm	1-3/8“	36 mm	1-3/4“	46 mm
Anchor Plate Size*	5 x 5 x $1^{1}/_{4}$	127 x 140 x 32	6 x 7 x $1^{1}/_{2}$	152 x 178 x 38	7 x $7^{1}/_{2}$ x $1^{3}/_{4}$	178 x 191 x 44	9 x 9 x 2	230 x 230 x 57
Anchor Plate Size*	4 x $6^{1}/_{2}$ x $1^{1}/_{4}$	102 x 165 x 32	5 x 8 x $1^{1}/_{2}$	127 x 203 x 38	5 x $9^{1}/_{2}$ x $1^{3}/_{4}$	127 x 241 x 44	-	-
Nut Extension a	1-$^{7}/_{8}$	48	$2^{1}/_{2}$	64	$2^{3}/_{4}$	70	$2^{7}/_{8}$	74
Min. Bar Protrusion **B	3	76	$3^{1}/_{2}$	89	4	102	$3^{5}/_{8}$	92
*other plate sizes available on special order. **To accommodate stressing								
Coupler Details								
Length C								
For plain bars	$6^{1}/_{4}$	159	$6^{3}/_{4}$	171	$8^{3}/_{4}$	219	$6^{3}/_{4}$	171
For epoxy coated bars	$7^{3}/_{4}$	197	$8^{1}/_{4}$	210	$10^{1}/_{8}$	267	$8^{3}/_{4}$	222
Diameter d	2	51	$2^{3}/_{8}$	60	$2^{3}/_{4}$	67	$3^{1}/_{8}$	79
Duct Details (galvanized steel)								
Bar Duct O.D.	$1^{7}/_{8}$	47	2	51	$2^{1}/_{8}$	55	$2^{3}/_{4}$	70
Bar Duct I.D.	$1^{5}/_{8}$	43	$1^{7}/_{8}$	48	2	51	$2^{5}/_{8}$	67
Coupler Duct O.D.	$2^{3}/_{4}$	70	3	76	$3^{1}/_{2}$	87	4	101
Coupler Duct I.D.	$2^{5}/_{8}$	67	$2^{7}/_{8}$	72	$3^{1}/_{4}$	83	$3^{3}/_{4}$	95
Duct Details (plastic duct)								
Bar duct OD	$2^{7}/_{8}$	73	$2^{7}/_{8}$	73	$2^{7}/_{8}$	73	$2^{7}/_{8}$	73
Bar duct ID	$2^{9}/_{32}$	63	$2^{9}/_{32}$	63	$2^{9}/_{32}$	63	$2^{9}/_{32}$	63
Coupler duct OD	$2^{7}/_{8}$	73	$3^{9}/_{16}$	90.5	$3^{7}/_{8}$	98.4	$4^{17}/_{32}$	115
Coupler duct ID	$2^{9}/_{32}$	63	3	76	$3^{1}/_{4}$	82.5	$3^{15}/_{16}$	100
Pocket Former Details								
Depth	$7^{1}/_{8}$	178	8	203	$8^{5}/_{8}$	219	N/A	N/A
Maximum Diameter	$5^{1}/_{8}$	130	$6^{1}/_{2}$	165	$6^{1}/_{2}$	165	N/A	N/A

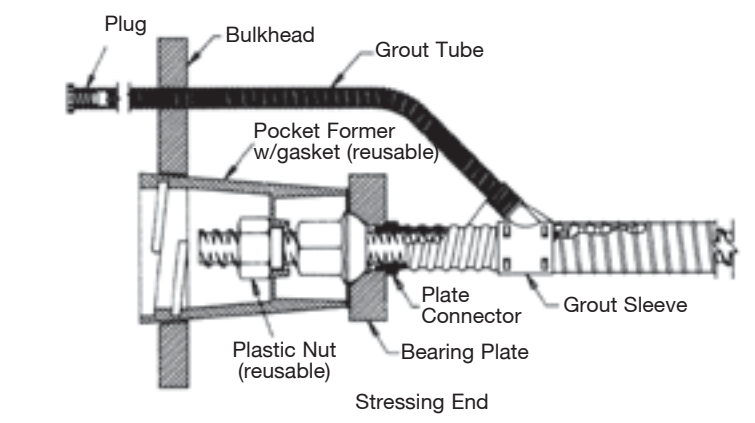
Plate Anchorage



Coupler



Pocket Former Detail



2-1/2“	66 mm
12 x 14 x 2 1/2	305 x 356 x 63.5
-	-
5	127
5 3/8	136.5
10 3/4	273
10 3/4	273
4 1/2	114
3 15/32	88
3 9/32	83.7
5 7/16	138
5 1/4	134
3 7/8	98.4
3 1/4	82.5
6	152.4
5	127
N/A	N/A
N/A	N/A

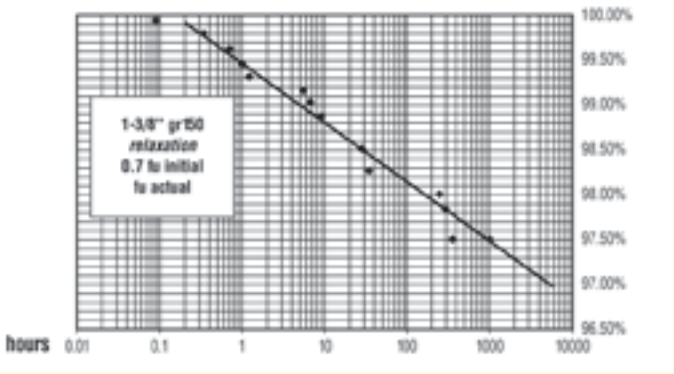
Modulus of Elasticity

The modulus of elasticity „E“ is an intrinsic property of steel whose magnitude remains basically constant and is little affected by normal variations in mill processes.
For Threadbars this value has been determined to be 29,700 ksi (205 MPa).

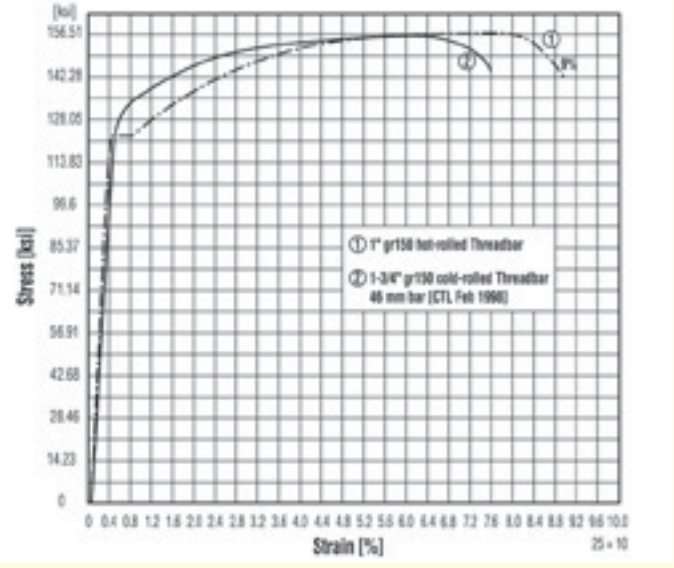
Relaxation

Relaxation is defined as the loss of prestress load in a post-tensioning steel subjected to a specified initial stress while maintaining the length and the temperature constant. Relaxation tests are usually conducted at an initial load equal to 70% of the strand‘s actual ultimate strength (see chart below). The tension loss after 1,000 hrs for a THREADBAR® initially stressed to 70% of guaranteed ultimate strength can be assumed between 1.5 and 2%.Tests indicate that the relaxation losses in cold drawn, cold threaded bars are significantly higher.

Relaxation



Stress-strain characteristics



Stress-strain characteristics

A typical stress-strain curve for a stretched and stress relieved bar is substantially different from a typical curve produced for a cold drawn, cold threaded bar. Samples of each are illustrated below.The most notable feature is the lack of a definite yield point characteristic of cold drawn bars.

Fatigue strength

Under normal circumstances fatigue is not a primary design consideration for prestressing steels. However, all DYWIDAG bars and accessories have been tested and proven to exceed the fatigue requirements specified by the Post-Tensioning Institute.

Temperature characteristics

Tests have demonstrated that no significant loss of strength occurs when bars are subjected to elevated temperatures up to 1,100 degrees F (593° C). Only the yield strength is reduced when temperatures exceed approximately 750 degrees F (399° C). Bar ductility is not significantly affected by temperatures down to -60 degrees F (-51° C).

Susceptibility to stress corrosion cracking and hydrogen embrittlement

All prestressing steel is susceptible to stress corrosion cracking and hydrogen embrittlement in aggressive environments and therefore must be properly protected. However, accelerated tests have demonstrated that while A 416 strand failed after 5 to 7 hours, bars still held their load when testing was discontinued at 200 hours.

Bond

The deformations on the DYWIDAG THREADBAR® exceed the deformation requirements of A 615. Consequently bond strength is at least equivalent to A 615 reinforcing bars.

Shear

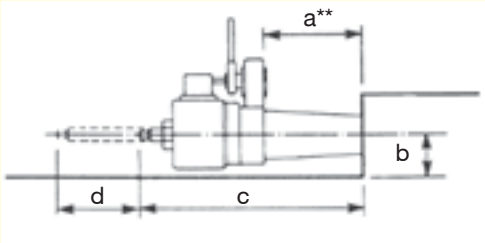
High strength bars are not usually used to resist transverse shear loads. However, their untensioned shear strength is similar to that of any other steel.

$$t = \frac{fy}{\sqrt{3}}$$

Stressing

DYWIDAG Threadbars are stressed using compact lightweight hydraulic jacks. In most cases handled by one man, the jack fits over a pull rod designed to thread over the THREADBAR® protruding from the anchor nut. The jack nose contains a socket wrench and ratchet device which allow the nut to be tightened as the THREADBAR® elongates. $1^{3}/_{4}$“ and $2^{1}/_{2}$“ bars utilize specially equipped center-hole stressing jacks.

The magnitude of the prestressing force applied is monitored by reading the hydraulic gauge pressure and by measuring the THREADBAR® elongation. The elongation can be measured directly by noting the change in threadbar protusion.



d = Total tendon elongation

Jack Capacity	Kips kN	67 267	160 712	220 979	330* 1,500	630* 2,800
Bar Size	in mm	$^{5}/_{8}$ 15	1, $1^{1}/_{4}$ 26, 32	$1^{1}/_{4}$, $1^{3}/_{8}$ 32, 36	$1^{3}/_{4}$ 46	$2^{1}/_{2}$ 66
a**	in mm	$7^{3}/_{4}$ 197	$8^{1}/_{2}$ 216	11 279	N/A	N/A
b	in mm	$3^{1}/_{4}$ 83	4 102	6 152	6 145	7 180
Min. c	in mm	24 610	26 660	30 762	36 900	43 1,070
Weight	lbs Kg	50 23	80 36	110 50	334* 152	500 227

* This system should have a mechanical means of lifting and moving.
** Special nose extensions for deep stressing pockets are available on request.

NOTE: Detailed operating and safety instructions are provided with all stressing and grouting units. Read and understand these instructions before operating equipment.

Grouting

Grouting completes the installation process for post-tensioned concrete construction.The grout is important in protecting the steel from corrosion and contributes significantly to the ultimate strength of the structure.

After mixing, the grout is injected into a low point vent until consistent material is exhausted at the terminating or anchorage vent. An admixture may be used to control expansion and pumpability.

CG 500

THREADBAR® Stressing Operation
Mopac Freeway/US 183 Interchange Austin, TX.

Temporary Threadbars for Precast
Segmental Construction

Typical THREADBAR® Tendon Installation,
Aeration/Equalization Basin McIntosh, AL

Bridge Repair THREADBAR® Stays Route 580
Altamont Pass, California

Inspection and Repair of Grouted Tendons
With over twenty years of experience in the field of inspection and repair of structures, DSI offers a complete service package that includes Non-Destructive Testing (NDT) for the non-invasive detection of flaws in structures, in particular, problems of voids in grouted post-tensioning tendons. DSI also offers special equipment such as metal sensitive drills and videoscopes for the limited invasive inspection at suspect locations in the structure, digital volumeters that measure the volume of any void inside the tendon and vacuum grouting equipment for subsequent filling of the void.

Non-Destructive Testing (NDT)
DSI's procedures for NDT include locating the ducts in the concrete using Ground Penetrating Radar (GPR), then using Impact Echo instrumentation to determine the location of any voids located inside the grouted tendons.

Locating tendons using GPR

Using Impact Echo to locate voids in the tendon

Vibration testing of external tendons

Vibration Testing
Vibration Testing is an economical and efficient procedure used to determine the amount of force existing in external tendons. The method consists of an external sensor located on the tendon to be tested and then generating a vibration in the tendon. The tendon response is recorded and analyzed with special software that will compute, based on the tendon characteristics, the remaining force in the tendon.

Grout Remediation of PT Tendons
DSI uses vacuum grouting techniques & experienced personnel to fill any voids. As a necessary check, the volume of material injected in the void should be compared to the volume previously measured.

DSI uses only ASBI certified grout technicians cross trained in NDT inspection. All technicians have extensive experience in both pressure and vacuum grouting techniques employing thixotropic grout.

Invasive Inspections
The NDT inspection shall be followed by limited invasive inspection to verify the NDT findings. DSI offers special devices and techniques developed to minimally invade the structure in order to determine the actual conditions of the grouted tendons and protect the prestressing steel during the inspection.

Volume Measuring
DSI is able to determine the volume of the void through the use of a Digital Volumeter with leak compensating capabilities.

Digital Volumeter with leak compensating capabilities

Result of void grouted with conventional methods

Result of void grouted with Vacuum Grouting

Repair of the Trent Street Bridge, Spokane, WA
Washington Department of Transportation

DSI performed an NDT inspection using Ground Penetrating Radar to detect post-tensioning ducts and steel reinforcement as well as an Impact Echo Scanner to detect voids in the grouted ducts. Videoscope inspections were carried out to assess the condition of the post-tensioning strands. The volume of voids inside the ducts was measured with state-of-the-art equipment capable of compensating for air leaks. The grouting remediation of the post-tensioned tendons in web b was performed using vacuum grouting.

DSI Services Inspection: NDT (GPR and Impact Echo), Special drills with shut-off capabilities when in contact with metal, Videoscope and Void volume measurement with air leak compensation capabilities / Repair: Vacuum Grouting

Mid Bay Bridge, Destin, FL
Mid Bay Bridge Authority

Inspection at anchorage areas of external tendons of the bridge and vacuum grouting of voids.

DSI Services Inspection and Measurement of the Volume of Voids / Repair: Vacuum injected more than 700 voids Engineering: Assisted in preparing procedures for detensioning and replacement of 11 external tendons

C & D Canal Bridge, SR1 over Chesapeake & Delaware Canal, St. Georges, New Castle Co., Delaware
Delaware Department of Transportation

DSI Services NDT inspection, by videoscope, of 18 cable stay guide pipes at the stays and NDT, limited invasive inspection and vacuum grouting of the anchorages of the external P.T. tendons in the bridge

I-88 & I-355 Interchange, Downer Grove, IL
The Illinois State Toll Highway Authority

Overall inspection of the post-tensioning tendons of 4 segmental ramps. Inspection included both, tendons in the superstructure as well as in the substructure.

DSI planned and performed NDT and limited invasive inspection in a selected sample of the post-tensioning tendon population of these ramps and assessed the condition of those elements of the structure (i.e. condition of the prestressing steel and grout).

DSI Services Preparation and implementation of the inspection plan. Inspection included the use of GPR, IE, vibration testing of external tendons, drillings, videoscope, volume measurement of the voids found inside the ducts and report preparation

Half Pipe

DSI's half pipe is the perfect solution for cracked or cracking HDPE external grouted ducts.

Developed to be installed in difficult access contitions, the Half Pipe snaps into place over an existing HDPE duct and has been engineered so that the annular spaces can be pressure grouted; restoring the tendon to it's original corrosion protection specifications.

The DSI Half Pipe also allows for the complete removal of the existing HDPE pipe to assess the condition of the grout and strands, if required, prior to its installation.

Cracked HDPE Duct

Simulated Repair of Cracked HDPE (White Pipe) duct using Half Pipe (Outer black Pipe). Annulus between pipes has been grouted.

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