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WVT-QA-8303

Measurement of Bore Roundness

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Product
Assurance
Directorate

Watervliet Arsenal
Watervliet, New York
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LVDT

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

In process (After honing, before rifling) diameter checks of the 8 inch gun tube failed to detect an out of round condition caused by a worn machine bearing. Excessive groove depth variations discovered on final inspection eventually led to the development of an in-process measurement device capable of detecting out of roundness conditions in the tube bore.

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

MATERIALS TESTING TECHNOLOGY PROGRAM (AMS 4931)

Report No. WVT-QA-8303

Title: Gun Tube Bore Roundness Measurement System

THIS PROJECT HAS BEEN ACCOMPLISHED AS PART OF THE US ARMY MATERIALS TESTING TECHNOLOGY PROGRAM, WHICH HAS FOR ITS OBJECTIVE THE TIMELY ESTABLISHMENT OF TESTING TECHNIQUES, PROCEDURES OR PROTOTYPE EQUIPMENT (IN MECHANICAL, CHEMICAL, OR NONDESTRUCTIVE TESTING) FOR MATERIEL/MATERIAL PROCURED OR MAINTAINED BY AMC.

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1. INTRODUCTION

The 8 inch M201 Howitzer is the largest production gun tube currently manufactured at Watervliet Arsenal. The manufacturing sequence for the internal features consists of boring, honing and rifling. At each step the inside diameter (ID) is measured before proceeding to the next operation. The rifling grooves are produced by broaching. The helix of the rifling is generated by rotating the broaches as they are pushed through the tube. After the tube is rifled, the final bore inspection takes place on a computerized gun tube inspection station where measurements of bore diameter, rifling groove diameter and eccentricity are made. Eccentricity is determined by making measurements of groove depth at diametrically opposed points, calculating the algebraic difference between the two measurements, and dividing the result by two. This eccentricity value represents the offset of the center point of these diameters.

The in process diameter measurements referenced above are taken with a two-point measurement device. This type of measurement technique is incapable of detecting certain geometric irregularities that can occur in the bore. This project was proposed as a result of a lobing condition in the bore of the 8 inch gun tube that went undetected until the final inspection. Groove depth variations of up to .015 inches were reported. It was therefore requested that a measurement system be developed to detect out of round conditions in the bore before the rifling grooves are cut in the tube.

2. BACKGROUND

The machinist operating the hone machine of the 8 inch production line utilizes a two-point star gage to check bore diameter. A star gage is a mechanical measuring instrument that is composed of three major assemblies: the measuring head, the staff, and the operating handle (Figure 1).

Measuring Head --The heart of the measuring head is a tapered cone attached to an actuating rod. Movement of the rod imparts motion to the cone, which, in turn actuates a set of movable bushings to which measuring points are attached. As the bushings are forced out at angles of 90° to the axis of the cone, the measuring points extend outward and make contact with the surface to be measured.

The Staff --The outer cylinder of the staff serves as a rigid connecting member between the measuring head and the operating handle. The inner rod, supported coaxially with the outer cylinder, permits longitudinal movement of the inner rod and forms a connecting link which transmits motion from the operating handle to the measuring head.

The Operating Handle --A venier scale, graduated in .001 inch increments, attached to the operating handle provides direct translation of the diametral movements of the measuring points.

This instrument is fairly rugged, simple and well suited for use in a shop environment. Typical accuracy is $\pm$ .001. It is not suited, however, for performing a more detailed assessment of the interior geometry of the tube. It can be shown that lobing conditions created in the tube bore can conceal themselves to certain measurement methods. Generally, an even lobing condition (2, 4, 6...) must be inspected with a two-point system or can go undetected. An odd lobing condition (3, 5, 7...) must be inspected with a three point measurement system. The solution therefore was to build a system employing both two point and three point measurement probes, the outputs of which would be compared electronically for the detection of out of round conditions in the tube bore.

An alternate solution is to scan or trace the tube bore with a rotating head. Many firms in the metrology field offer highly sophisticated tracing equipment with computer analysis for determination of component roundness conditions. Initially, this sort of technique seemed to be the solution to this problem. After a more thorough analysis, it was decided that a continuous tracing type system was too complex, too fragile and too difficult to set up, for use on a regular basis in a gun tube manufacturing line.

3. SYSTEM DESCRIPTION

A measurement head was designed by the Quality Engineering Division of the Product Assurance Directorate and built by an outside contractor (See Figure 2). The head was to be manually pushed through the tube bore and rotated at each selected inspection point. A performance specification (Appendix) was prepared for the electronic equipment. This equipment, purchased from an outside contractor, includes the measurement probes and the system console (Figure 3) which houses the amplifiers, displays and printer. Assembly of the entire system was accomplished in-house.

The measurement head assembly (Figure 4) contains a floating spindle for two-point measurement. One end has a fixed tip while the other end houses a linear variable differential transformer (LVDT) the output of which gives an indication of tip position. This LVDT as mounted, outputs the deviation from a set "zero" diameter to the electronic console. The three point diameter measurement is accomplished by means of a similar LVDT mounted axially in the gage head. A mechanism causes motion of the three balls that contact the bore surface to be transferred to the LVDT. This movement is calibrated to correspond to the change in diameter being measured.

As the head is rotated in a perfectly round bore the readings from the two-point and three-point LVDTs will all remain equal and constant. An out of round condition will lead to variations between the two LVDTs. The digital electronic system captures and holds the positive (most positive or least negative) peak and the negative (least positive or most negative) peak values from the LVDT analog amplifiers caused by the variations in bore size detected as the head is rotated. Since there are two LVDTs, four extreme values are retained. Upon command from either a front panel switch or a remote cable switch, the system prints the four peak values, annotated with the appropriate LVDT identification and the calculated runout. The runout is the difference between the algebraic maximum and the algebraic minimum of the four values. Shown below is the printer output with typical data.

09	1.859
08	1.255
07	3.114
06	1.554
05	2.259

Channel 05 is the positive peak from LVDT #1, 06 the negative peak; channel 07 is the positive peak from LVDT #2, 08 the negative peak; and channel 09 is the calculated runout. Channel 01 through 04 are for instantaneous readout of the LVDTs' position. All values are shown in MILs (.001 inch); the amplifiers may be converted and recalibrated to read metric values (millimeters).

4. IMPLEMENTATION

A set check (master ring) was fabricated to calibrate the system. Following testing of the unit, several tubes were measured and found acceptable. The eight inch gun tube line can now be monitored on a systematic basis to assure that rifling of out of round gun bores does not occur in the future.

5. RECOMMENDATIONS AND CONCLUSIONS

This system meets the design parameters established at the inception of this project. The overall system accuracy exceeds functional requirements. The mechanical subsystem is rugged and reliable. The electronic subsystem, however, needs modification before it can perform reliably in the abusive environment found in the manufacturing areas. Specifically; the system console must be sealed against the intrusion of dust and grit, and the electronic circuits must be hardened against electrical interference and noise. Provisions should also be made to limit access to the controls and adjustments to prevent unauthorized adjustments once the unit is calibrated.

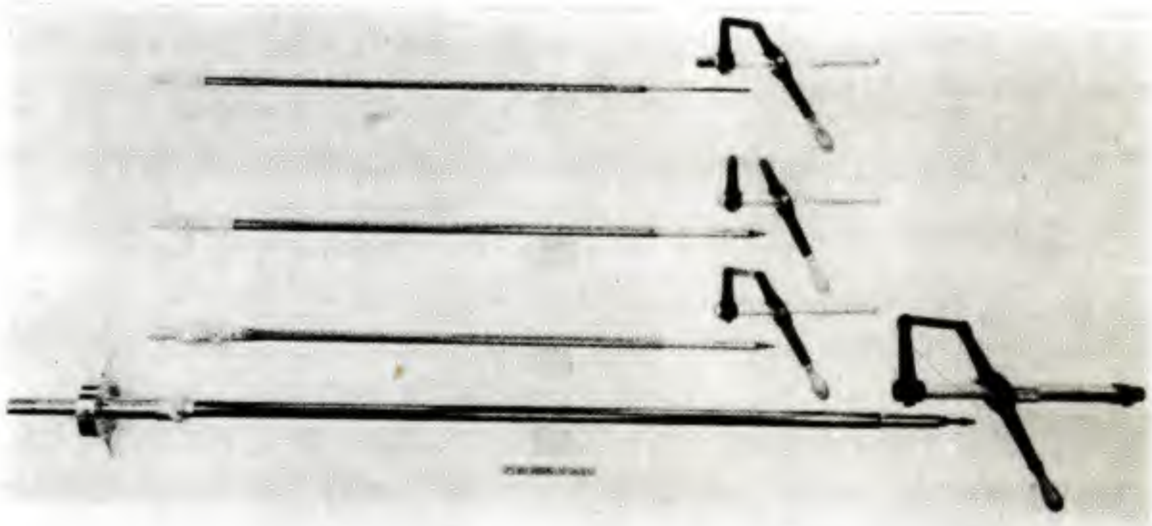

FIGURE 1. STARGAGE ASSEMBLIES

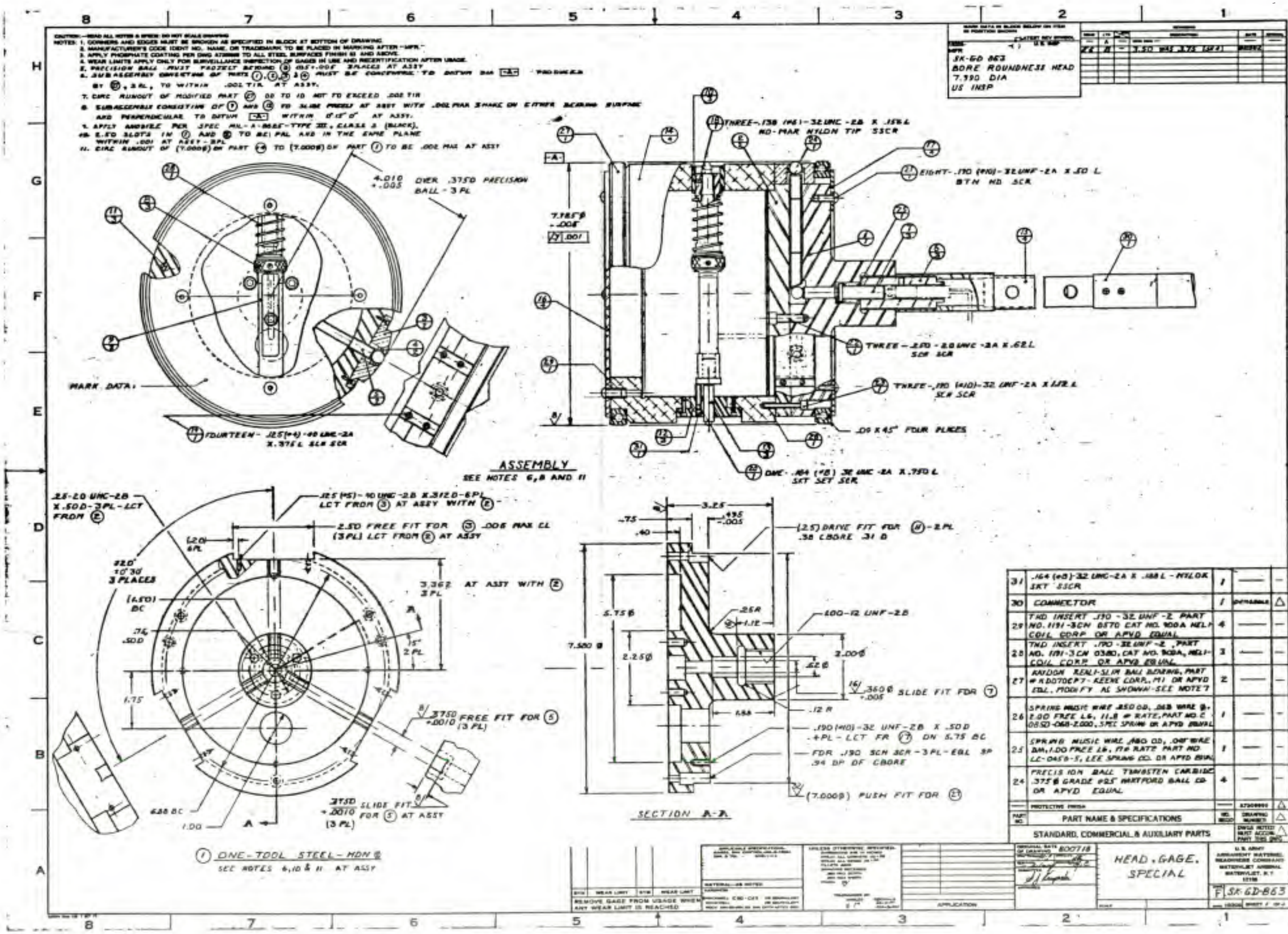

FIGURE 2. MEASUREMENT HEAD

FIGURE 3. SYSTEM CONSOLE

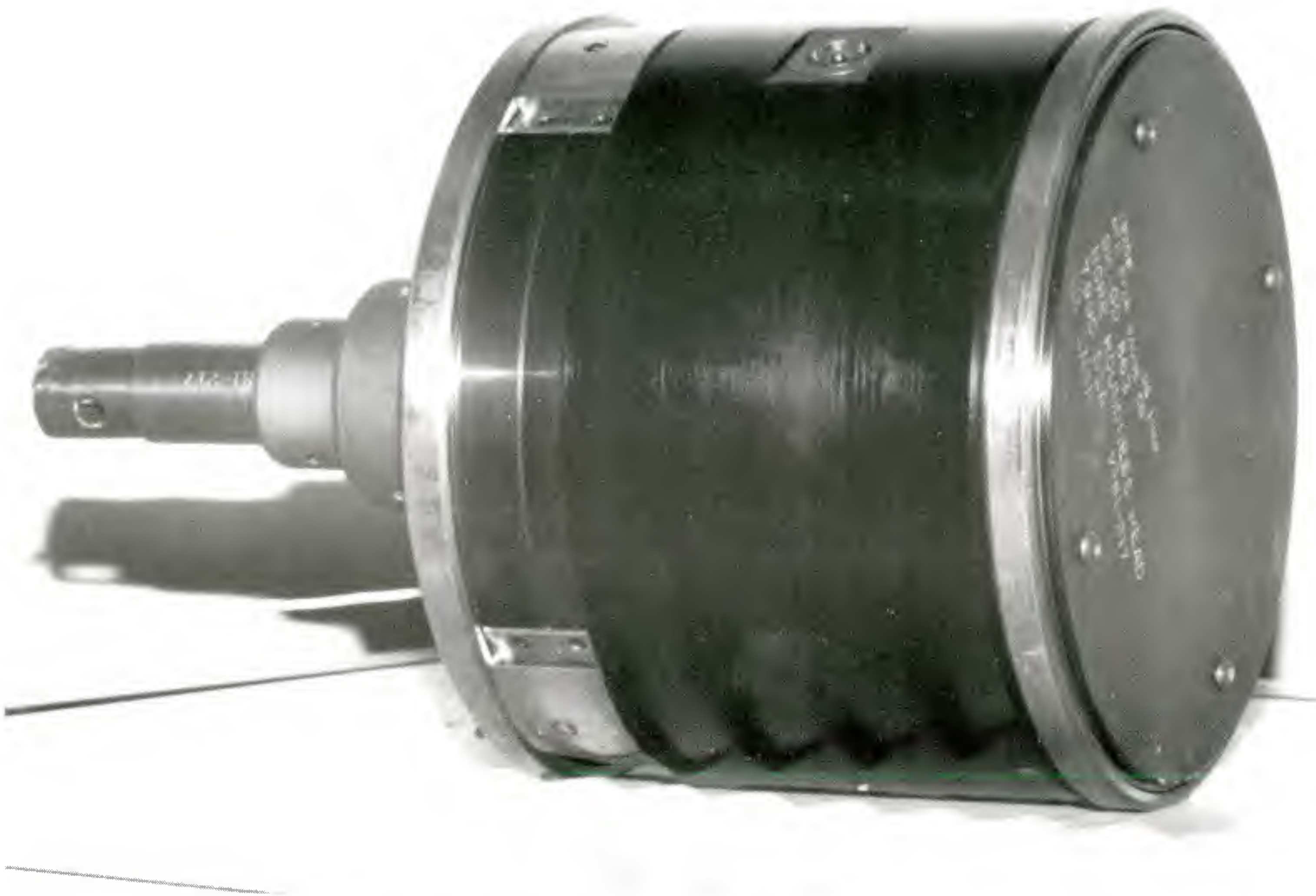

FIGURE 4. MEASUREMENT HEAD ASSEMBLY

APPLICATION		REVISIONS				
NEXT ASSY	USED ON	SYM	DESCRIPTION	DATE	APP'D	MICRO-FILMED
	CANNON 8 IN M201	A	ERR-WVQ-08570	800710	—	(M)

PURCHASE DESCRIPTION FOR ANCILLARY ELECTRONIC EQUIPMENT
FOR CANNON BORE ROUNDNESS SYSTEM

1. SCOPE

THIS DOCUMENT CONTAINS REQUIREMENTS FOR THE ANCILLARY ELECTRONIC EQUIPMENT FOR THE CANNON BORE ROUNDNESS MEASUREMENT SYSTEM. SECTION 3 COVERS GENERAL AND DETAILED TECHNICAL REQUIREMENTS. SECTION 4 COVERS QUALITY ASSURANCE PROVISIONS, TESTING AND ACCEPTANCE CRITERIA. SECTION 5 PROVIDES PACKAGING AND DELIVERY INSTRUCTIONS AND SECTION 6 PROVIDES INSTRUCTIONS DESIGNED TO ASSIST OFFERORS IN MAKING ACCEPTABLE BIDS OR PROPOSALS.

2. APPLICABLE STANDARDS AND PUBLICATIONS

N/A

3. REQUIREMENTS

THE ELECTRONIC EQUIPMENT SHALL CONSIST OF:

A. TWO (2) LINEAR VARIABLE DIFFERENTIAL TRANSFORMER CARTRIDGES WITH BALL GAGING TIPS.

B. ONE (1) MODULAR INSTRUMENT SYSTEM WITH READOUT, PRINTER, AND REMOTE PRINT/RESET CABLE (WITH SWITCHES).

C. EXTENSION CABLE

3.1 DETAILS

3.1.1 LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS (LVDT) (QUANTITY REQUIRED: 2)

3.1.1.1 LVDT SHALL BE THREADED TO ACCEPT A #4-48 THREAD 0.156 INCH DIAMETER SPHERICAL CARBIDE CONTACT TIP WHICH WILL BE INCLUDED WITH EACH CARTRIDGE.

3.1.1.2 CARTRIDGE LENGTH INCLUDING 0.156 INCH DIAMETER CARBIDE BALL:

FREE LENGTH -----------2.10 ± .25 INCH

ORIGINAL DATE OF DRAWING 800710		DEPT OF THE ARMY WATERVLIET ARSENAL WATERVLIET, N. Y.
DFT T. McCLOSKEY	CHK JA	PURCHASE DESCRIPTION
TR	CHK	
ENGR T. McCloskey	ENGR A.J. Kmpski	
SUBMITTED J.J. Andrews		A — CODE 19206 — 11586192
APPROVED A. J. Gallo		SCALE NONE — REV — SHEET 1 OF 5

3.1.1.3 CARTRIDGE BODY DIAMETER IS TO BE .375 - .001 INCH AND CONTACT END IS TO BE THREADED WITH .375-40 THD/IN X .625 LENGTH OF THREAD.

3.1.1.4 THE CARTRIDGE HOUSING IS TO BE OF STAINLESS STEEL AND CABLE CONNECTOR LOCATION IS TO BE AT THE END (REAR OF HOUSING).

3.1.1.5 CABLE LENGTH ON LVDT IS TO BE 2 FEET SHIELDED AS NECESSARY TO PREVENT DEGRADATION OF TRANSDUCER SIGNAL.

3.1.1.6 CONNECTOR IS TO BE AN AMPHENOL 165.33 OR AN APPROVED EQUAL. NOTE: CONNECTOR MUST FIT IN A 1.00 INCH DIAMETER HOLE.

3.1.1.7 LVDT SHALL HAVE A GAGING RANGE OF ± .0200 INCH WITH AN OVER-TRAVEL OF .055 INCH AND A PRETRAVEL OF .005 INCH (MIN). THE GAGING FORCE OF THE LVDT SHALL BE 2 TO 4 OUNCES.

3.1.1.8 LVDT IS TO HAVE LINEARITY AT FULL RANGE OF ±.2%.

3.1.2 MODULAR INSTRUMENT SYSTEM

3.1.2.1 SYSTEM SHALL BE COMPRISED OF MODULAR SOLID STATE ELECTRONIC UNITS ENCLOSED IN A PORTABLE INDUSTRIAL ENCLOSURE. MORE THAN ONE, BUT NOT MORE THAN THREE ENCLOSURES IS PERMISSIBLE. IF MORE THAN ONE ENCLOSURE IS REQUIRED, EACH ENCLOSURE SHALL BE PROPERLY INTERFACED BY QUICK DISCONNECT CABLES SHIELDED AS NECESSARY TO PREVENT DEGRADATION OF SIGNALS.

3.1.2.2 SYSTEM SHALL INTERFACE TO THE LVDT'S AND PROVIDE FOR EXCITATION AND AMPLIFICATION OF THE LVDT'S VIA EXTENSION CABLE (SEE PARA 3.1.3).

3.1.2.3 SYSTEM SHALL HAVE A RESET FUNCTION WHICH CAN BE ACTIVATED BY TWO WAYS; EITHER BY A FRONT PANEL PUSH BUTTON SWITCH OR BY A RESET PUSH BUTTON SWITCH ON THE PRINT CABLE.

3.1.2.4 THE RESET FUNCTION SHALL, UPON ACTIVATION, CLEAR ANY PREVIOUS MEMORY CONDITION AND PREPARE TO ACCEPT READINGS. ALSO, A LIGHT EMITTING DIODE (LED) RESET INDICATOR WILL BE DEACTIVATED.

3.1.2.5 THE SYSTEM SHALL RETAIN, INDEFINITELY, WITHOUT DECAY, POSITIVE AND NEGATIVE PEAK VALUES OF THE ANALOG INPUTS FROM THE LVDT'S. A + PEAK VALUE IS DEFINED AS THE ALGEBRAIC MAXIMUM (MOST POSITIVE OR LEAST NEGATIVE) LVDT INPUT. A - PEAK VALUE IS DEFINED AS THE ALGEBRAIC MINIMUM (LEAST POSITIVE OR MOST NEGATIVE) LVDT INPUT. FOR EXAMPLE: SHOWN ARE THREE CASES OF FOUR VALUES OF WHICH THE MINIMUM AND MAXIMUM VALUES ARE ALSO SHOWN (NOTE: CASE III CONTAINS POSITIVE AND NEGATIVE VALUES).

CASE

	I	II	III
VALUES	+3	-4	+2
	+2	-3	+1
	+5	-2	-3
	+1	-1	-4
+PEAK (MAX)	+5	-1	+2
-PEAK (MIN)	+1	-4	-4

THUS, FOUR EXTREME VALUES ("PEAKS") ARE TO BE RETAINED.

MAXIMUM INPUT VALUE FROM LVDT #1
MINIMUM INPUT VALUE FROM LVDT #1
MAXIMUM INPUT VALUE FROM LVDT #2
MINIMUM INPUT VALUE FROM LVDT #2

3.1.2.6 THERE SHALL BE NO PEAK MEMORY DELAY. THE RESPONSE TIME FOR ACQUISITION OF THE PEAK VALUES SHALL BE 99.9% OF TRUE VALUE OF A 5 MILLISECOND PULSE OR BETTER.

3.1.2.7 UPON PRINT COMMAND (VIA EITHER A FRONT PANEL SWITCH OR PRINT CABLE SWITCH) THE SYSTEM SHALL PRINT THE FOUR PEAK VALUES WITH ANNOTATION AS TO WHICH GAGE HEAD THEY ARE FROM. IN ADDITION, THE DIFFERENCE BETWEEN THE ALGEBRAIC MAXIMUM OF THESE FOUR VALUES AND THE ALGEBRAIC MINIMUM OF THESE FOUR VALUES IS TO BE PRINTED. THE PRINTER WILL PRINT THE VALUES WITH A ± SIGN, DECIMAL POINT, LVDT DESIGNATION, AND INDEX ONE LINE FOR EACH VALUE PRINTED IN THE FORMAT SHOWN BELOW OR AN APPROVED EQUAL.

A	±.XXXX	← MAX LVDT 1
A	±.XXXX	← MIN LVDT 1
B	±.XXXX	← MAX LVDT 2
B	±.XXXX	← MIN LVDT 2
	.XXXX	← DIFFERENCE

LVDT DESIGNATION

UPON THIS COMMAND, THE SYSTEM WILL ALSO ACTIVATE THE RESET INDICATOR.

3.1.2.8 THE INDIVIDUAL LVDT INPUTS SHALL BE AVAILABLE FOR DISPLAY VIA A DIGITAL DISPLAY. A FRONT PANEL SELECTOR SWITCH WILL CONTROL WHICH LVDT IS TO BE DISPLAYED. THE SWITCH IS TO BE SUITABLY LABELED TO IDENTIFY EACH LVDT INPUT. THE DISPLAY SHALL CONSIST OF FOUR DIGITS, DECIMAL POINT, LEGEND (INCH/MM), ± SIGN AND IS TO PROVIDE READOUT OF .0001 (INCH), AND, WHEN SWITCHED TO METRIC, PROVIDE READOUT OF .002 (METRIC). THE RESOLUTION OF THE LEAST SIGNIFICANT DIGIT IS ONE TEN-THOUSANDTH OF AN INCH (.XXXX) AND WHEN DISPLAYING METRIC, IS TWO THOUSANDTH'S OF A MILLIMETER (.XXX). THE MINIMUM HEIGHT OF THE DIGITS IS TO BE .60 INCH. THE RANGE OF THE DISPLAY SHALL SHOW THE FULL MEASUREMENT RANGE OF THE LVDT CARTRIDGES.

3.1.2.9 THE SYSTEM SHALL HAVE A REMOTE PRINT/RESET SWITCH CABLE WITH TWO LABELED PUSHBUTTON SWITCHES THAT WILL SUPPLY A PRINT COMMAND WHEN ONE SWITCH IS ACTIVATED AND RESET THE SYSTEM WHEN THE OTHER SWITCH IS ACTIVATED. THE CABLE SHALL HAVE A LENGTH OF 20 FEET (MINIMUM) AND IS TO HAVE A QUICK DISCONNECT CONNECTOR TO INTERFACE WITH THE INSTRUMENT SYSTEM.

3.1.3 <u>ELECTRICAL EXTENSION CABLE</u>

3.1.3.1 THE ELECTRICAL EXTENSION CABLE SHALL HAVE A LENGTH OF 40 FEET (MINIMUM) AND SHIELDED AS NECESSARY TO PREVENT DEGRADATION OF TRANSDUCER SIGNALS.

3.1.3.2 THE FRONT TERMINATION SHALL BE TWO (2) AMPHENOL 165.34 OR APPROVED EQUAL TO MATE WITH THE LVDT'S. THE REAR TERMINATION SHALL BE A SUITABLE QUICK DISCONNECT CONNECTOR TO MATE WITH THE INSTRUMENT SYSTEM.

3.2 POWER REQUIREMENTS FOR THE COMPLETE SYSTEM SHALL BE 115V ±10%, 60 HZ (FUSED INPUT).

3.3 ACCURACY OF THE INSTRUMENT SYSTEM IS TO BE ±.0001 INCH OF ACTUAL VALUES. THIS ACCURACY APPLIES TO THE INDIVIDUAL VALUES PRINTED AND TO THE VALUES DISPLAYED.

3.4 <u>MANUALS</u>; THREE COPIES OF AN INSTRUCTION MANUAL INCLUDING PARTS BREAKDOWN SHALL BE PROVIDED. THESE MANUALS SHALL INCLUDE COMPLETE DETAILED INSTRUCTIONS COVERING OPERATION, MAINTENANCE AND CALIBRATION OF THE EQUIPMENT AND ITS COMPONENTS. THESE MANUALS SHALL ALSO INCLUDE SCHEMATIC DIAGRAMS OF ELECTRICAL AND MECHANICAL SYSTEMS.

3.4.1 A LIST OF COMMERCIALLY AVAILABLE COMPONENTS INCORPORATED IN THIS SYSTEM WILL BE PROVIDED LISTING MANUFACTURER AND MODEL NUMBER FOR ASSISTANCE IN REPAIRS OR REPLACEMENT OF PARTS AS NECESSARY.

3.4.2 A LIST OF RECOMMENDED REPAIR PARTS AND PRICE ESTIMATES SHALL BE PROVIDED. ANY SUBSTANTIAL ADVANTAGES INCURRED BY ORDERING SPARES AT THE SAME TIME AS THE ORIGINAL SYSTEM (SPECIAL PRODUCTION COMPONENTS, ETC) SHALL BE NOTED IN THE SYSTEM PROPOSAL.

4. <u>QUALITY ASSURANCE PROVISIONS</u>

4.1 THE CONTRACTOR SHALL PERFORM EXAMINATION AND TEST FOR CONFORMANCE WITH SECTION 3. THE EXAMINATION AND TEST WILL BE PERFORMED PRIOR TO SHIPMENT TO WATERVLIET ARSENAL. COPIES OF THE EXAMINATION AND TEST RESULTS SHALL BE PROVIDED TO THE ARSENAL PRIOR TO SHIPMENT.

4.2 AFTER SHIPMENT TO WATERVLIET ARSENAL, THE SYSTEM SHALL BE EXAMINED AND TESTED FOR CONFORMANCE WITH SECTION 3. FINAL TESTING AND ACCEPTANCE WILL BE AT THE ARSENAL. DESIGN AND PERFORMANCE OF THE SYSTEM MUST BE IN ACCORDANCE WITH THE REQUIREMENTS OF THIS DOCUMENT. FAILURE TO COMPLY SHALL BE CAUSE FOR REJECTION.

4.3 IN THE EVENT OF REJECTION THE CONTRACTOR SHALL BE RESPONSIBLE TO MAKE NECESSARY CHANGES TO THE ELECTRONIC EQUIPMENT SO THAT IT MEETS THE REQUIREMENTS OF THIS DOCUMENT. CONTRACTOR SHALL CONFORM TO THE REQUIREMENTS OF THIS DOCUMENT AND RESHIP THE ELECTRONIC EQUIPMENT TO THE ARSENAL SUCH THAT THE CORRECTED EQUIPMENT IS BACK AT WATERVLIET ARSENAL NO LATER THAN 30 DAYS AFTER THE CONTRACTOR HAS RECEIVED THE REJECTED EQUIPMENT FROM WATERVLIET.

5. PRESERVATION, PACKAGING AND DELIVERY

THE CONTRACTOR SHALL UTILIZE STANDARD COMMERCIAL METHODS OF PRESERVATION AND PACKAGING APPROPRIATE FOR ELECTRICAL INSTRUMENTS AND ACCEPTABLE TO COMMERCIAL CARRIERS. AS A MINIMUM, ALL AREAS SUSCEPTIBLE TO DAMAGE FROM EXPOSURE TO THE ELEMENTS SHALL BE PRESERVED AND/OR PACKED TO PREVENT DAMAGE. THE EQUIPMENT SHALL BE BLOCKED, BRACED AND SKIDDED TO PREVENT DAMAGE DURING THE TRANSPORT AND TO FACILITATE HANDLING, LOADING AND UNLOADING. THE CONTRACTOR SHALL BE RESPONSIBLE FOR INSURING THAT THE EQUIPMENT IS DELIVERED TO WATERVLIET ARSENAL IN GOOD CONDITION AND SHALL RETAIN THIS RESPONSIBILITY UNTIL THE EQUIPMENT IS OFF-LOADED AT WATERVLIET ARSENAL BY ARSENAL PERSONNEL.

6. LITERATURE REQUIREMENTS

6.1 BIDDER SHALL SUBMIT, IN TRIPLICATE, BROCHURES, CUTS, ILLUSTRATIONS, DRAWINGS OR A NARRATIVE DESCRIPTION WHICH CLEARLY INDICATES THAT THE DESIGN, CONSTRUCTION AND OPERATING FEATURES OF THE MACHINE AND RELATED ACCESSORIES OFFERED WILL MEET ALL OF THE REQUIREMENTS. THE LITERATURE SUBMITTED MUST INDICATE THE OVERALL SIZE AND CONFIGURATION OF THE MACHINE AND RELATED COMPONENT PARTS, SUCH AS BED, ROLLERS, DIGITAL READOUT DISPLAY, AND ELECTRONIC SYSTEM ASSURING THAT THE RANGES AND CAPACITIES WILL BE MET BY THE MACHINE BEING OFFERED. THIS DATA IS REQUIRED FOR EVALUATION OF EQUIPMENT OFFERED AND PROPOSALS SUBMITTED WITHOUT IT WILL BE REJECTED.

6.2 LITERATURE COVERING MORE THAN ONE MODEL OR SIZE MUST BE CLEARLY MARKED TO INDICATE THE EXACT MODEL AND SIZE BEING PROPOSED.

6.3 IN ADDITION TO THE FOREGOING, OFFERORS MUST INDICATE ON A PARAGRAPH BY PARAGRAPH BASIS, WHETHER OR NOT THEY COMPLY WITH EACH PARAGRAPH OF THIS SPECIFICATION. OFFERORS DEVIATING IN ANY RESPECT FROM A SPECIFIC PARAGRAPH(S) MUST DESCRIBE IN DETAIL HOW THEY PROPOSE TO COMPLY WITH THE PARTICULAR REQUIREMENT(S) THEREIN. FOR EXAMPLE:

PARA 3.1 THRU 3.2.8 -------------WE COMPLY
PARA 3.3 THRU 3.3.5 -------------WE COMPLY
PARA 3.3.5.1 --------------------WE PROPOSE TO FURNISH, ETC.

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