SECTION 40 90 00 – PROCESS CONTROL AND INSTRUMENTATION SYSTEMS

PART 1 - GENERAL

1.1 THE REQUIREMENT

A. The CONTRACTOR shall provide all Process Control and Instrumentation Systems (PCIS), less programming, complete and operable, in accordance with the Contract Documents. All programming and configuration shall be done by the ENGINEER and OWNER.

B. The requirements of this Section apply to all components of the PCIS, unless indicated otherwise.

C. Responsibilities
   1. The CONTRACTOR, through the use of an Instrumentation Supplier, panel fabricator, and qualified electrical and mechanical installers, shall be responsible to the OWNER for the implementation of the PCIS and the integration of the PCIS with other required instrumentation and control devices.
   2. Due to the complexities associated with the interfacing of numerous control system devices, it is the intent of these Specifications that the Instrumentation Supplier be responsible to the CONTRACTOR for the integration of the PCIS with devices provided under other sections, with the objective of providing a completely integrated control system free of signal incompatibilities.
   3. As a minimum, the Instrumentation Supplier shall perform the following WORK:
      a. Implementation of the PCIS
         1) prepare analog hardware submittals
         2) prepare the test plan, the training plan, and the spare parts submittals
         3) procure hardware
         4) oversee and certify hardware installation
         5) oversee, document, and certify loop testing
         6) prepare Technical Manuals
         7) prepare edited set of record drawings
   4. Any Instrumentation Supplier responsibilities in addition to the list above are at the discretion of the CONTRACTOR and the Instrumentation Supplier. Additional requirements in this Section and throughout Division 40 which are stated to be the CONTRACTOR's responsibility may be performed by the Instrumentation Supplier if the CONTRACTOR and Instrumentation Supplier so agree.

D. Control System Panel Designer and Fabricator
   1. Control System Panel Designer and Fabricator (CSPDF): The control system panel, and all other panels that have PLC hardware or communication hardware within them, shall be fabricated by the CSPDF. The CSPDF shall perform the following work:
      a. Edit contract loop drawings and control panel designs to show any and all changes to the design.

b. Fabricate and Test the panel(s) at the factory.
c. Ship the panel with a copy of the marked up drawings.

2. CSPDF Qualifications: The CSPDF shall have the resources, space, and personnel needed to design and fabricate the panels. The CSPDF shall meet the following minimum qualifications:
   a. The CSPDF shall have been in the business of building panels and bonding the construction of these panels for at least 5 years. The bonding shall be under the name and ownership of the company fabricating the panels for this project.
   b. The CSPDF shall build the panels to UL standard 508A, shall be certified to build panels to UL standard 508A, and shall attach a UL label on all new panels, or the panel builder shall build to an equal standard, shall be certified to an equal standard, and shall attach a label to all new panels with a label that is acceptable to the Municipality of Anchorage Building Department.
   c. The CSPDF shall make all wiring changes to new and existing control panels. The changes shall be made to UL standard 508, or equal standard that is acceptable to the Municipality of Anchorage Building Department. The CSPDF shall provide a UL engineer, or equal testing lab engineer that is acceptable to the Municipality of Anchorage Building Department, to inspect the changes and certify that the panel meets the standard, or provide a list of deficiencies.
3. The CSPDF shall be experienced with building AWWU Systems. Acceptable OEM Manufacturers include:
   a. TecPRO, Anchorage, Alaska
   b. Dowland-Bach, Anchorage, Alaska
   c. Technical Systems Inc, (TSI), Lynnwood, Washington

1.2 CONTRACTOR SUBMITTALS

A. Furnish submittals in accordance with MASS Section 10.05 Article 5.6 and the following:
   1. The CONTRACTOR shall coordinate the instrumentation work so that the complete instrumentation and control system will be provided and will be supported by accurate Shop Drawings and record drawings.
   2. Exchange of Technical Information: During the period of preparation of these submittals, the CONTRACTOR shall authorize a direct, informal liaison with the ENGINEER for exchange of technical information. As a result of this liaison, certain minor refinements and revisions in the systems as indicated may be authorized informally by the ENGINEER, but will not alter the scope of work or cause increase or decrease in the Contract Price. During this informal exchange, no oral statement by the ENGINEER shall be construed to give approval of any component or method, nor shall any statement be construed to grant exception to or variation from these Contract Documents.
   3. Symbology and Nomenclature: In these Contract Documents, all systems, all meters, all instruments, and all other elements are represented schematically, and are designated by symbology as derived from Instrument Society of America Standard ANSI/ISA S5.1 – Instrumentation Symbols and Identification. The nomenclature and numbers designated herein and on the Contract Drawings

shall be employed exclusively throughout Shop Drawings, and similar materials. No other symbols, designations, or nomenclature unique to the manufacturer's standard methods shall replace those prescribed above, used herein, or on the Contract Drawings.

B. Shop Drawings
   1. General
      a. Shop Drawings shall include the letterhead or title block of the Instrumentation Supplier. The title block shall include, as a minimum, the Instrumentation Supplier's registered business name and address, project name, drawing name, revision level, and personnel responsible for the content of the drawing. The quantity of submittal sets shall be as indicated in MASS Section 10.05 Article 5.6.
      b. Organization of the Shop Drawing submittals shall be compatible with eventual submittals for later inclusion in the Technical Manual.
      c. Shop Drawing information shall be bound in standard size, three-ring, loose-leaf, vinyl plastic, hard cover binders suitable for bookshelf storage. One set of drawings for each facility is to be hung inside the SCADA panel. The drawings are to be enclosed in PVC pockets suitable for hanging from a 3-ring binder, two drawings per pocket. The ring binder is to be attached to the inside of the front panel door.
      d. Interfaces between instruments, motor starters, control valves, variable speed drives, flow meters, chemical feeders and other equipment related to the PCIS shall be included in the Shop Drawing submittal.
   2. Analog Hardware Submittal: The CONTRACTOR shall submit an analog hardware submittal as a complete bound package at one time within 60 calendar days after the commencement date stated in the Notice to Proceed, including:
      a. A complete index which lists each device by tag number, type, and manufacturer. A separate technical brochure or bulletin shall be included with each instrument data sheet (original documents only – photocopies are not acceptable and will be rejected). The data sheets shall be indexed in the submittal by systems or loops, as a separate group for each system or loop. If, within a single system or loop, a single instrument is employed more than once, one data sheet with one brochure or bulletin may cover all identical uses of that instrument in that system. Each brochure or bulletin shall include a list of tag numbers for which it applies. System groups shall be separated by labeled tags.
      b. Fully executed data sheets according to ISA-S20 – Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves, for each component, together with a technical product brochure or bulletin. The technical product brochures shall be complete enough to verify conformance to all Contract Document requirements. The data sheets, as a minimum, shall show:
         1) Component functional description used in the Contract Documents
         2) Manufacturer's model number or other product designation
         3) Project tag number used in the Contract Documents
         4) Project system or loop of which the component is a part
         5) Project location or assembly at which the component is to be installed

6) Input and output characteristics
7) Scale, range, units, and multiplier (if any)
8) Requirements for electric supply (if any)
9) Requirements for air supply (if any)
10) Materials of component parts to be in contact with or otherwise exposed to process media and corrosive ambient air
11) Special requirements or features

c. Priced list of all spare parts for all devices.

d. Instrument installation, mounting, and anchoring details shall be submitted in an electronic hard copy format. Each instrument shall have a dedicated 8-1/2-inch by 11-inch detail which only pertains to the specific instrument by tag number. Each detail shall be certified by the instrument manufacturer that the proposed installation is in accordance with the instrument manufacturer's recommendations and is fully warrantable. These certifications shall be embedded in the CAD files and also appear as a stamp on the hard copies. As a minimum, each detail shall have the following contents:
1) Show all necessary sections and elevation views required to define instrument location by referencing tank, building or equipment names and numbers, and geographical qualities such as north, south, east, west, basement, first floor.
2) Process line pipe or tank size, service and material.
3) Process tap elevation and location.
4) Upstream and downstream straight pipe lengths between instrument installation and pipe fittings and valves.
5) Routing of tubing and identification of supports.
6) Mounting brackets, stands, and anchoring devices.
7) Conduit entry size, number, location, and delineation between power and signal.
8) NEMA ratings of enclosures and all components.
9) Clearances required for instrument servicing.
10) List itemizing all manufacturer makes, model numbers, quantities, lengths required, and materials of each item required to support the implementation of the detail.

3. Test Procedure Submittals
a. The CONTRACTOR shall submit the proposed procedures to be followed during tests of the PCIS and its components.
b. Preliminary Submittal: Outlines of the specific proposed tests and examples of proposed forms and checklists.

4. The CONTRACTOR shall provide a submittal of the CSPDF's certifications, P.E. licenses, and project history before submitting any Shop Drawings or commencing any work on the control panels.

C. Technical Manual
   1. General: Information in the Technical Manual shall be based upon the approved Shop Drawing submittals as modified for conditions encountered in the field during the WORK.
   2. The Technical Manual shall have the following organization for each process:
      a. Section C – Edited As-Built Drawings
      b. Section D – Instrument Summary
      c. Section E – Instrument Data Sheets
      d. Section G – Instrument Installation Details
      e. Section H – Test Results
   3. Signed results from Loop Testing and FAT test.
   4. Initially, two sets of draft Technical Manuals shall be submitted for review after return of favorably reviewed Shop Drawings and data required herein. Following the ENGINEER's review, one set will be returned to the CONTRACTOR with comments. The Manuals shall be revised and amended as required and the final Manuals shall be submitted 15 days prior to start-up of systems.
   5. The CONTRACTOR shall provide Instrument Equipment Summary Form 1302 CM 1207 for all instruments, PLC hardware, devices, control hardware, and miscellaneous equipment. The data shall be provided in electronic format, **Microsoft Excel**, or approved equal.

D. Record Drawings
   1. The CONTRACTOR shall keep current a set of complete loop and schematic diagrams which shall include all field and panel wiring, piping and tubing runs, routing, mounting details, point to point diagrams with cable, wire, tube and termination numbers. These drawings shall include all instruments and instrument elements. Two sets of drawings electronically formatted in AUTOCAD on CD-ROM and two hard copies shall be submitted after completion of all commissioning tasks. All such drawings shall be submitted for review prior to acceptance of the completed work by the OWNER.

1.3 WARRANTY

A. The warranty shall start from the date of final acceptance of the completed project, and shall extend for 1 year, in accordance with MASS Division 10.

PART 2 - PRODUCTS

2.1 GENERAL

A. Code and Regulatory Compliance: PCIS WORK shall conform to or exceed the applicable requirements of the National Electrical Code and local building codes.

B. Current Technology: Meters, instruments, and other components shall be the most recent field-proven models marketed by their manufacturers at the time of submittal of the Shop Drawings, unless otherwise required to match existing equipment.

C. Hardware Commonality: Instruments which utilize a common measurement principle (for example, d/p cells, pressure transmitters, level transmitters which monitor hydrostatic head) shall be furnished by a single manufacturer. Panel-mounted instruments shall have matching style and general appearance. Instruments performing similar functions shall be of the same type, model, or class, and shall be from a single manufacturer.

D. Loop Accuracy: The accuracy of each instrumentation system or loop shall be determined as a probable maximum error; this shall be the square root of the sum of the squares of certified "accuracies" of the designated components in each system, expressed as a percentage of the actual span or value of the measured variable. Each individual instrument shall have a minimum accuracy of plus and minus 2 percent of full scale and a minimum repeatability of plus and minus 1 percent of full scale when installed in the field, unless otherwise indicated. Instruments that do not conform to or improve upon these criteria are not acceptable.

E. Instrument and Loop Power: Power requirements and input/output connections for all components shall be verified. Power for transmitted signals shall, in general, originate in and be supplied by the control panel devices. The use of "2-wire" transmitters is preferred, and use of "4-wire" transmitters shall be minimized. Individual loop or redundant power supplies shall be provided as required by the manufacturer's instrument load characteristics to ensure sufficient power to each loop component. Power supplies shall be mounted within control panels or in the field at the point of application.

F. Loop Isolators and Converters: Signal isolators shall be provided as required to ensure adjacent component impedance match where feedback paths may be generated, or to maintain loop integrity during the removal of a loop component. Dropping precision wirewound resistors shall be installed at all field side terminations in the control panels to ensure loop integrity. Signal conditioners and converters shall be provided where required to resolve any signal level incompatibilities or provide required functions.

G. Environmental Suitability: Indoor and outdoor control panels and instrument enclosures shall be suitable for operation in the ambient conditions associated with the locations designated in the Contract Documents. Heating, cooling, and dehumidifying devices shall be provided in order to maintain all instrumentation devices 20 percent within the minimums and maximums of their rated environmental operating ranges. The CONTRACTOR shall provide power wiring for these devices. Enclosures suitable for the environment shall be furnished. All instrumentation in hazardous areas shall be suitable for use in the particular hazardous or classified location in which it is to be installed.

H. Signal Levels: Analog measurements and control signals shall be as indicated herein, and unless otherwise indicated, shall vary in direct linear proportion to the measured variable. Electrical signals outside control panels shall be 4 to 20 mA DC, except as indicated. Signals within enclosures may be 1 5 VDC. Electric signals shall be electrically or optically isolated from other signals. Pneumatic signals shall be 3 to 15 psig, with 3 psig equal to 0 percent, and 15 psig equal to 100 percent.

I. Alternative Equipment and Methods: Equipment or methods requiring redesign of any project details are not acceptable without prior written approval of the ENGINEER through the "or equal" process of MASS Section 10.05 Article 5.7. Any proposal for approval of alternative equipment or methods shall include evidence of improved performance, operational advantage and maintenance enhancement over the equipment or method indicated, or shall include evidence that an indicated component is not available. To match existing equipment and future equipment being installed under other contracts, equipment substitutions for equipment specified as no equal will not be accepted.

J. Instrument Brackets and Mounting Hardware: All instrument brackets and mounting hardware shall be stainless steel.

2.2 OPERATING CONDITIONS

A. The PCIS shall be designed and constructed for satisfactory operation and long, low maintenance service under the following conditions:

1.	Environment	-	water treatment/supply facility
2.	Indoor Temperature Range	-	32 through 84 degrees F
3.	Relative Humidity	-	20 through 90 percent, non-condensing
4.	Seismic Zone 4		

2.3 SPARE PARTS AND SPECIAL TOOLS

A. The CONTRACTOR shall provide the following:
   1. Spare parts as listed in equipment specifications in Division 40.

B. The CONTRACTOR shall furnish a priced list of all special tools required to calibrate and maintain the instrumentation provided under the Contract Documents. After approval, the CONTRACTOR shall furnish tools on that list.

C. Special tools and spare parts shall be submitted before startup commences, suitably wrapped and identified.

PART 3 - EXECUTION

3.1 PRODUCT HANDLING

A. Shipping Precautions: After completion of shop assembly, factory test, and approval, equipment, cabinets, panels, and consoles shall be packed in protective crates and enclosed in heavy-duty polyethylene envelopes or secured sheeting to provide complete protection from damage, dust, and moisture. Dehumidifiers shall be placed inside the polyethylene coverings. The equipment shall then be skid-mounted for final transport. Lifting rings shall be provided for moving without removing protective covering. Boxed weight shall be shown on shipping tags together with instructions for unloading, transporting, storing, and handling at the Site.

B. Special Instructions: Special instructions for proper field handling, storage, and installation required by the manufacturer shall be securely attached to each piece of equipment prior to packaging and shipment.

C. Tagging: Each component shall be tagged to identify its location, instrument tag number, and function in the system. A permanent stainless steel tag firmly attached and stamped with the instrument tag number, as given in the tabulation, shall be provided on each piece of equipment in the PCIS. Identification shall be prominently displayed on the outside of the package. Each HART device shall have the PID number programmed into smart HART protocol memory. The complete tag shall be the instrument drawing tag shown on the contract drawings.

D. Storage: Equipment shall not be stored outdoors. Equipment shall be stored in dry, permanent shelters, including in-line equipment, and shall be adequately protected against mechanical injury. If any apparatus has been damaged, such damage shall be repaired by the CONTRACTOR. If any apparatus has been subject to possible injury by water, it shall be thoroughly dried out and put through tests as directed by the ENGINEER. If such tests reveal defects, the equipment shall be replaced.

3.2 INSTALLATION

A. General
   1. Instrumentation, including instrumentation furnished under other Divisions, shall be installed under Division 40 and the manufacturers' instructions.
   2. Equipment Locations: The monitoring and control system configurations indicated are diagrammatic. The locations of equipment are approximate. The exact locations and routing of wiring and cables shall be governed by structural conditions and physical interferences and by the location of electrical terminations on equipment. Equipment shall be located and installed so that it will be readily accessible for operation and maintenance. Where job conditions require reasonable changes in approximated locations and arrangements, or when the OWNER exercises the right to require changes in location of equipment which do not impact material quantities or cause material rework, the CONTRACTOR shall make such changes without additional cost to the OWNER.

B. Conduit, Cables, and Field Wiring
   1. Conduit shall be provided under Division 26.
   2. Process equipment control wiring, 4-20 mA signal circuits, signal wiring to field instruments, PLC input and output wiring and other field wiring and cables shall be provided under Division 26.
   3. PLC equipment cables, Control Area Networks shall be provided under Division 40.
   4. Terminations and wire identification at PCIS equipment furnished under this or any other Division shall be provided under Division 40.

C. Instrumentation Tie-Downs: Instruments, control panels, and equipment shall be anchored by methods that comply with seismic requirements applicable to the Site.

D. Existing Instrumentation: Each existing instrument to be removed and reinstalled shall be cleaned, reconditioned, and recalibrated by an authorized service facility of the instrument manufacturer. The CONTRACTOR shall provide certification of this work prior to reinstallation of each instrument.

E. Ancillary Devices: The Contract Documents show all necessary conduit and instruments required to make a complete instrumentation system. The CONTRACTOR shall be responsible for providing any additional or different type connections as required by the instruments and specific installation requirements. Such additions and such changes, including the proposed method of installation, shall be submitted to the ENGINEER for approval prior to commencing the WORK. Such changes shall not be a basis of claims for extra work or delay.

F. Installation Criteria and Validation: Field-mounted components and assemblies shall be installed and connected according to the requirements below:
   1. Installation personnel have been instructed on installation requirements of the Contract Documents.
   2. Technical assistance is available to installation personnel at least by telephone.
   3. Installation personnel have at least one copy of the approved Shop Drawings and data.
   4. Instrument process sensing lines shall be installed under Section 22 11 19 – Piping and Tubing Systems.
   5. Flexible cables and capillary tubing shall be installed in flexible conduits. The lengths shall be sufficient to withdraw the element for periodic maintenance.
   6. Power and signal wires shall be terminated with crimped type lugs.
   7. Connectors shall be, as a minimum, watertight.
   8. Wires shall be mounted clearly with an identification tag that is of a permanent and reusable nature.
   9. Wire and cable shall be arranged in a neat manner and securely supported in cable groups and connected from terminal to terminal without splices, unless specifically approved by the ENGINEER. Wiring shall be protected from sharp edges and corners.
   10. Fasteners using adhesives are not permitted.
   11. Mounting stands and bracket materials and workmanship shall comply with requirements of the Contract Documents.
   12. Verify the correctness of each installation, including polarity of electric power and signal connections, and make sure process connections are free of leaks. The CONTRACTOR shall certify in writing that discrepancies have been corrected for each loop or system checked out.
   13. The OWNER will not be responsible for any additional cost of rework attributable to actions of the CONTRACTOR or the Instrumentation Supplier.

3.3 CALIBRATION

A. General: Devices provided under Division 40 shall be calibrated according to the manufacturer's recommended procedures to verify operational readiness and ability to meet the indicated functional and tolerance requirements.

B. Calibration Points: Each instrument shall be calibrated at 20, 60, and 100 percent of span using test instruments to simulate inputs. The test instruments shall have accuracies traceable to National Institute of Testing Standards.

C. Bench Calibration: Instruments that have been bench-calibrated shall be examined in the field to determine whether any of the calibrations are in need of adjustment. Such adjustments, if required, shall be made only after consultation with the ENGINEER.

D. Field Calibration: Instruments that were not bench-calibrated shall be calibrated in the field to insure proper operation in accordance with the instrument loop diagrams or specification data sheets.

E. Analyzer Calibration: Each analyzer system shall be calibrated and tested as a workable system after installation. Testing procedures shall be directed by the manufacturers' technical representatives. Samples and sample gases shall be furnished by the manufacturers.

F. Calibration Sheets: Each instrument calibration sheet shall provide the following information and a space for sign-off on individual items and on the completed unit:
   1. Project name
   2. Loop number
   3. Tag number
   4. Manufacturer
   5. Model number
   6. Serial number
   7. Calibration range
   8. Calibration data: Input, output, and error at 20 percent, 60 percent and 100 percent of span
   9. Switch setting, contact action, and deadband for discrete elements
   10. Space for comments
   11. Space for sign-off by Instrumentation Supplier and date
   12. Test equipment used and associated serial numbers

G. Calibration Tags: A calibration and testing tag shall be attached to each piece of equipment or system at a location determined by the ENGINEER. The CONTRACTOR shall have the Instrumentation Supplier sign the tag when calibration is complete. The ENGINEER will sign the tag when the calibration and testing has been accepted.

3.4 LOOP TESTING

A. General: Individual instrument loop diagrams per ISA Standard S5.4 - Instrument Loop Diagrams, expanded format, shall be submitted to the ENGINEER for review prior to the loop tests. The CONTRACTOR shall notify the ENGINEER of scheduled tests a minimum of 30 days prior to the estimated completion date of installation and wiring of the PCIS. After the ENGINEER's review of the submitted loop diagrams for correctness and compliance with the Specifications, loop testing shall proceed. The loop check shall be witnessed by the ENGINEER.

B. Control Valve Tests: Control valves, cylinders, drives and connecting linkages shall be stroked from the operator interface units as well as local control devices and adjusted to verify proper control action, hand switch action, limit switch settings, torque settings, remote control actions, and remote feedback of valve status and position. Control valve actions and positioner settings shall be checked with the valves in place to insure that no changes have occurred since the bench calibration.

C. Instrument and Instrument Component Validation: Each instrument shall be field-tested, inspected, and adjusted to its indicated performance requirement in accordance with manufacturer's specifications and instructions. Any instrument which fails to meet any Contract requirement, or, in the absence of a Contract requirement, any published manufacturer performance specification for functional and operational parameters, shall be repaired or replaced, at the discretion of the ENGINEER and at the CONTRACTOR’s expense.

D. Loop Validation: Controllers and electronic function modules shall be field-tested and exercised to demonstrate correct operation of the hardware and wiring. Control loops shall be checked under simulated operating conditions by impressing input signals at the primary control elements and observing appropriate responses at register in the PLC processor. Actual signals shall be used wherever available. Following any necessary corrections, the loops shall be retested.

E. Loop Validation Sheets: The CONTRACTOR shall prepare loop confirmation sheets for each loop covering each active instrumentation and control device including simple hand switches and lights. Loop confirmation sheets shall form the basis for operational tests and documentation. Each loop confirmation sheet shall cite the following information and shall provide spaces for sign-off on individual items and on the complete loop by the Instrumentation Supplier:
   1. Project name
   2. Loop number
   3. Tag number, description, manufacturer and model number for each element
   4. Installation bulletin number
   5. Specification sheet number
   6. Adjustment check
   7. Space for comments
   8. Space for loop sign-off by Instrumentation Supplier and date
   9. Space for ENGINEER witness signature and date

F. Loop Certifications: When installation tests have been successfully completed for all individual instruments and all separate analog control networks, a certified copy of each test form signed by the ENGINEER or the ENGINEER's representative as a witness, with test data entered, shall be submitted to the ENGINEER together with a clear and unequivocal statement that the instrumentation has been successfully calibrated, inspected, and tested.

3.5 RADIO SYSTEM TEST

A. Two measurements are to be made during the initial installation. They will confirm proper operation of the unit and serve as a benchmark in troubleshooting should difficulties appear in the future. These measurements must be performed by a skilled radio-technician and are: Antenna System SWR (Standing-Wave Ratio), and Antenna Direction Optimization, as defined below.

B. Antenna System SWR and Transmitter Power Output

1. General: A proper impedance match between the MDS Entranet 900 radio and the antenna system is important. It ensures the maximum signal transfer between the radio and antenna. The impedance match can be checked indirectly by measuring the SWR of the antenna system. If the results are normal (as defined in the next paragraph), record them for comparison for use during future routine preventative maintenance. Abnormal readings indicate possible trouble with the antenna or the transmission line that must be corrected and the test then repeated.

   The SWR of the antenna system is to be checked before the radio is put into regular service. For accurate readings, a wattmeter suited to 1000 MHz measurements is required. One unit meeting this criterion is the **Bird Model 43** directional wattmeter with a **5J** element installed. The reflected power must be less than 10 percent of the forward power (≈2:1 SWR).

   If the reflected power is more than 10 percent, check the feedline, antenna and its connectors for damage and repair or replace as necessary.

   Set the transmitter power output level to 30 dBm for the duration of the test to provide an adequate signal level for the directional wattmeter.

2. Use the following Microwave Data Systems recommended test procedure:
   a. Place a directional wattmeter between the ANTENNA connector and the antenna system.
   b. Place the MDS unit into the Radio Test Mode.
   c. Set the transmitter power to 30 dBm and turn on the radio transmitter.
   d. Measure the forward and reflected power into the antenna system and calculate the SWR and power output level. The output should agree with the programmed value.

C. Antenna Direction Optimization

1. General: Directional antennas require some fine-turning of their bearing to optimize the received signal strength. The MDS radio has a built-in received signal strength indicator (RSSI) that is to be used to tell when the antenna is in a position that provides the optimum received signal.

   RSSI measurements and Wireless Packet Statistics are based on multiple samples over a period of several seconds. The average of these measurements will be displayed by the radio Management System.

   The measurement and antenna alignment process is expected to take 10 or more minutes.

2. Use the Microwave Data Systems recommended test procedure.
   a. Optimize RSSI (less negative is better) by slowly adjusting the direction of the antenna. Watch the RSSI indication for several seconds after making

each adjustment so that the RSSI accurately reflects any change in the link signal strength.

b. View the Wireless Packets Dropped and Received Error rates at the point of maximum RSSI level. They should be the same or lower than the previous reading. (Main Menu>Performance Information>Packet Statistics>Wireless Packet Statistics)

3.6 PERFORMANCE TEST

A. The entire PCIS hardware, field instruments, power supplies, and wiring shall operate for 30 days without failure.

B. The CONTRACTOR shall furnish support staff as required to satisfy the repair or replacement requirements.

C. If any component, other than field instruments, fails during the performance test, it shall be repaired or replaced and the PCIS shall be restarted for another 30-day period.

3.7 REQUIREMENTS FOR SUBSTANTIAL COMPLETION

A. For the purpose of this Section, the following conditions, in addition to the requirements in MASS Division 10, shall be fulfilled before the WORK is considered substantially complete:

1. Submittals have been completed and approved.
2. The PCIS has been installed, calibrated, and loop tested.
3. Spare parts and expendable supplies and test equipment have been delivered to the ENGINEER.
4. The performance test has been successfully completed.
5. Punch-list items have been corrected.
6. Record drawings in both hard copy and electronic format have been submitted.
7. Revisions to the Technical Manuals that may have resulted from the field tests have been made and reviewed.
8. Debris associated with installation of instrumentation has been removed.
9. Probes, elements, sample lines, transmitters, tubing, and enclosures have been cleaned and are in like-new condition.
10. Instrument Equipment Summary Forms 1302 CM-1207 have been accepted by the OWNER.

END OF SECTION 40 90 00