Guidelines
for
Conducting and Reporting on
Calibration, Testing and Verification of
Performance of Flow Measurement Instruments

Preamble

Under the WMO Project "Assessment of the Performance of Flow Measurement Instruments and Techniques", task number 4 is to develop guidelines for conducting and reporting results of flow instrumentation calibration and performance tests on instruments and techniques. Two specific sub-tasks are:

a) Establishment of protocols/specifications for instrument calibration and testing and verification of performance characteristics of instruments and techniques
b) Develop sample format for reporting testing and verification results

Subsequent to the creation of this task, the working group clarified its expectations to focus on field measurement instruments used to determine flow (including water level sensors, velocity meters, depth sensors, current profilers), and to have the documentation be very general guidance in nature. The goal is to allow NHS's to share and compare the results of their testing, while accepting that each NHS has its own instrument needs, testing methodologies, performance specifications/standards, and internal reporting requirements.

Sub-Task 4a: Protocols/specifications for calibration, testing, verification

To properly calibrate, test, and verify the performance of any instrument, NHS must first define the conditions under which the instrument will operate and its expected functionality to meet the needs of the NHS. The determination of these lead to the creation of instrument performance specifications, and can be captured in two main categories: environmental and technical. Performance specifications for any number of instruments can be developed using elements as listed below; please see Appendices 1, 2, 3 for examples of performance specifications for data loggers, pressure transducers, and shaft encoders.

ENVIRONMENTAL

- Wind
- Relative Humidity & Moisture
- Operating Temperatures
- Thermal Shock, Transportation (Mechanical Shock and Storage)
- Ice Accretion
- Sand & Dust
- Corrosion Protection
- Vibration
- Solar Radiation (for outdoor mounted instruments)

TECHNICAL

- Power Requirements
- Electromagnetic Interference
- Surge Protection, Transient Voltage and Current
- Memory Protection & Eprom Write Life Expectancy
- Input / Output Ports
- Accuracy
- Drift
- Resolution
- Conversion
- Range
- Response Time
- Calibration
- Float Pulley Assembly
- Shaft Diameter
- Rotation

- Torque
- Output Data
- Connectors
- Cables
- Telecommunications
- Satellite Transmitting Antenna
- Dimensions
- Clock Accuracy
- Programming Interface, Firmware and Software, Upgradability
- Sensor Management
- Data Acquisition Integrity/Quality Assurance/Quality Control Routines
- Data Storage
- Data Handling

The calibration, testing and verification of a given instrument would be against the applicable performance specifications for that instrument (ie: programming of a data logger, measurement range of a pressure transducer). The NHS should establish the calibration, testing and verification procedures that simulate actual operational conditions to the extent possible, including any unique conditions that may be encountered during operation (ie: smooth roll-over for leap year). If time permits, deployment in actual field conditions can be pursued. Please see Appendix 4 for an example of a data logger test procedure.

Sub-Task 4b – Reporting on instrument calibration, testing and verification results

It is recognized that individual NHS typically have internal guidelines for the production of reports, and this guideline is not meant to circumvent those guidelines. However, to enable the sharing of results across the hydrologic community at large to facilitate the comparison of instrumentation, the following is suggested for consideration when writing those reports. Example reports can be found in Appendix 4.

Introduction/Overview/(Executive Summary?)
- a brief description of the tested product(s), their purpose
- a brief (high level) description of the test procedures and results
    - could include a statement on how the results compare to the NHS's specifications/standards

Objective of the Test
- a short statement that summarizes the purpose of the test

Approach
- a short narrative on how the test was conducted

Description of Instrument(s)
- details of the product, its purpose, how it operates
- may include the manufacturer's product specifications

Test Procedures
- details of the test procedures, including performance specifications being used
- reference all instruments used as benchmarks for comparison, calibration

Test Results
- details on the findings, including how the instrument(s) performed against the NHS performance specifications, against benchmark instruments, etc
- include tables and graphs

Discussion of Results/Conclusions
- non-technical narrative on the results – explanation of specific findings, reasons for non-typical product performance

- conclusions based on the initial objective of the test

Related Observation/Comments
- non-subjective statements on observations made on the product as part of the testing.

References

Appendices

Document History

Rev#	Date	State	Description of Changes
Draft 1	Aug 11, 2009	WMO Working Group Review	First draft created by P. McCurry for concept review and discussion by WMO Working Group on Assessment of Performance of Flow Measurement Instruments and Techniques.

APPENDICES

Appendix 1
Performance Specifications for Data Logger

2.1 ENVIRONMENTAL SPECIFICATIONS - DATA LOGGER
(Referenced Military standard methodology will be used when testing for compliance is required)

1. Relative Humidity & Moisture	1. **MUST** withstand max. humidity 100% non condensing at 50°C & -40°C, min. humidity 3% at 50°C. 2. Casing **MUST** be water resistant.
2. Operating Temperatures	1. Equipment **SHALL** operate through an ambient temperature range of -40°C to +50°C, withstand temperatures from -60°C to +65°C and **MUST** automatically recommence normal operation when operating temperatures are achieved. 1. Cables **SHALL** remain flexible at -40°C (**MUST** not be brittle) and **SHALL** not deteriorate at +65°C.
3. Thermal Shock, Transportation (Mechanical Shock and Storage)	1. Equipment **SHALL** withstand instantaneous induced thermal shock during transport of 70° C (-50°C to +20°C) and **SHALL** operate under thermal shock of 15°C/min. for 2 minutes (-20°C to +10°C). 2. Equipment **SHALL** operate after experiencing a series of mechanical shocks equivalent to 18 impact shocks of 15g consisting of 3 shocks in each direction (6 total) applied to each of 3 mutually perpendicular axes of the equipment. Military Standard 810E, 516.4 (14 July 1989)
4. Corrosion Protection	1. Corrosion resistant materials **SHALL** be used.
5. Vibration	1. Equipment **SHALL** withstand transportation vibrations 10 – 50 Hz without being in a shipping container. Military Standard-167..
6. Sand & Dust	1. Sand and dust **MUST** not alter the operation of equipment.
7. Wind (for outdoor mounted components)	1. Equipment **MUST** withstand 5 second gusts up to 250 km/h and an average hourly wind speed of 160 km/h.
8. Ice Accretion (for outdoor mounted components)	1. Equipment **SHALL** operate under icing conditions of 50mm thickness and specific gravity of 0.9, at winds as specified above. Military Standard 810E, 521.1 (14 July 1989)
9. Solar Radiation (for outdoor mounted components)	1. Equipment and components **SHALL**: operate during periods of insolation intensity of 1022 $W/m^{2;}$ and ultra violet intensity of 64.5 $W/m^{2;}$ and withstand the effects of insolation intensity of 75.25 W/m^2. Military Standard 810E, 505.3 (July 14, 1989)

2.2 TECHNICAL SPECIFICATIONS - DATA LOGGER
(NOTE: unless specified otherwise, elements apply to Levels 1 & 2 loggers)

1. Power Requirements

1. Normal operating voltage **SHALL** be 11 VDC to 15 VDC with over voltage levels up to 20 VDC.
2. Minimum cut-off voltage **MUST** be 10.75 VDC.
3. Power consumption, excluding sensors, **SHALL** not exceed 50 m Amps on average while active and 10 m Amps on average while quiescent.
4. Power requirements of the instrument **MUST** be stated for all modes of operation and **SHALL** be protected for over, under and reverse voltages.
5. During power interruptions, the DATA LOGGER **MUST** maintain correct time and date references and resume logging when power returns to normal operational levels.
6. Backup batteries **MUST** support easy field replacement- not soldered in place.

2. Electromagnetic Interference

1. Equipment **SHALL** meet class A3 requirements of MIL-STD-461D for radiated emissions (RE102) and for radiated susceptibility (RS103).

3. Surge Protection, Transient Voltage and Current

1. The DATA LOGGER **MUST** withstand repeated power transients resulting from near lightning strikes.
2. Equipment **SHALL** conform to surge protection standards as detailed in ANSI standard C62.41 “Surge Protection in Low Voltage AC Power Circuits”, Class B.
3. Equipment **SHALL** not be affected by transient voltage and current originating from the power supply or other sources.

4. Memory Protection and EPROM Memory life write expectancy

1. During primary power interruption, memory related to the operating program and data archive **SHALL** be protected to maintain correct time and date reference, programmed parameters and data, for a period of not less than 90 days
1. Remote access to programming and set-up parameters **SHALL** be password protected.
1. The write to EPROM memory **SHALL** operate properly for a minimum of 10 years based on measurements at 5 minute intervals and 40 parameter changes per year.

5. Input / Output Ports

- Level 1

DATA LOGGER unit **MUST** have:

1. RS232: 1 serial port; used for DATA LOGGER and sensor configuration and data retrieval via direct connect PC or external data communications device, baud rate programmable up to at least 9600, compliant with RS232 standards.
2. SDI-12: 1 port (3 wire), minimum full SDI-12 capability using the latest (downward compatible) published version, (See Appendix A.5.3).

- Level 2

as above plus **MUST** have:

1. RS232: a second serial port identical to the above, with both ports individually programmable (Note: If only one RS232 port is provided, the supplier **MUST** demonstrate how that one port can provide the same functionality, including that of element 2.2.13.2, that two separate ports would provide);
2. Event: 1 port, minimum 16 bit counter, 20ms closure, rollover or reset software selectable.
3. Analog: 2 differential configurable up to 4 single ended; resolution 1 bit or 0.025% full scale; analog to digital conversion minimum 12 bits (plus one sign bit); range ±5 volts DC and accuracy 0.1% full scale, temperature compensated over full range of operating temperatures. (Note: if voltage range input is less than ±5 volts, supplier **MUST** demonstrate how the above accuracy can be achieved).(see Appendix A-4 for details of analog requirements)
4. Excitation: 2 ports, switched under software control, programmable from 0 to 5 V at 1% full scale resolution, accuracy at 0.1% full scale, range 0 to 5 volts DC, load compensated up to 20 m Amps; (Note: if voltage range output is less than ±5 volts, supplier **MUST** demonstrate how the above accuracy can be achieved).
1. Switched: one 12 VDC power output port to be used for sensor activation, that **SHALL** be enabled by software and **SHALL** have an output current of at least 750 m Amps.

6. Connectors

1. All connectors used for operation, maintenance, communication and sensor connection **MUST** be clearly labelled.
2. All connectors **SHALL** be equipped with a positive locking mechanism that will prevent inadvertent separation of the plug and socket.
3. All connectors containing a live wire end with the exception of the telephone RJ-11 **MUST** be female.
1. Sensor connection to the DATA LOGGER **SHALL** be by terminal strip or individual connectors or a combination thereof.
1. Insulation displacement connectors **SHALL** conform to the requirements of MIL-C-83503A.

7. Cables

- Level 1

1. A minimum 2.5 metre long power cable with appropriate connectors **SHALL** be supplied.
2. A minimum 1.5 metre long communication cable **MUST** be provided complete with a DB9 female connector on the computer end and an appropriate connector on the logger end.
3. If an external modem is supplied, a minimum 1.5 metre long communication cable between the modem and logger **MUST** be provided, complete with the appropriate environmental connectors.

- Level 2

as above plus:

1. If satellite antenna is supplied, a minimum 4.5 metre antenna cable **MUST** be supplied, complete with the appropriate environmental connectors.
1. If HDR transmitter and GPS antenna are supplied, a minimum 4.5 metre GPS antenna cable **MUST** be supplied, complete with the appropriate environmental connectors.

8.Telecommunications

1. DATA LOGGER firmware **MUST** support modem and GOES satellite telecommunications.
2. Telecommunications capability **MUST** be available as options to the logger, to be ordered as required.
3. Modem communications **MUST** be:
    1. supported via supplier modems or third party modems;
    2. via modems that are Canadian Department of Communications approved and are Hayes compatible;
    3. via modems programmable up to at least 9600 baud.
4. For GOES satellite communications:
    1. DATA LOGGER and transmitter (High Data Rate) **MUST** meet all criteria for GOES (NOAA/NESDIS March 2000. See Appendix A.5.1);
    2. DATA LOGGER **MUST** operate in random as well as self-timed transmission modes;
    3. DATA LOGGER **MUST** perform timing tests, including present time, time to next data acquisition and time to next transmission if integrated with self-timed transmitter, and single test transmission if integrated with random mode transmitter.
    4. The GOES output message length **MUST** be truncated by the DATA LOGGER to prevent trip of the fail safe (as per NESDIS High Data Rate specification)
5. GOES Satellite Transmitting Antenna:
    1. transmitting antenna **SHALL** be to NESDIS specifications.
    2. beam width **SHALL** be wide enough to include a pair of GOES satellites and **SHALL** deliver the maximum possible power to reach both satellites.
    3. Antenna **MUST** come complete with a 5m length antenna cable with appropriate environmental connectors and antenna mounting hardware.

9. Dimensions

1. The maximum size **SHALL** be 40 cm long x 40cm high x 35cm wide.

10. Clock Accuracy

- Level 1

1. Accuracy **MUST** be ±50 ppm per year.

- Level 2

1. For DATA LOGGER without GOES, accuracy **MUST** be ±50 ppm per year.
1. For DATA LOGGER with GOES, logger clock **MUST** be tuneable to GOES clock.
2. For DATA LOGGER with high data rate (HDR) GOES transmitter - the DATA LOGGER clock **MUST** be synchronised to the HDR GOES transmitter. The HDR 1200 bps GOES transmitter clock **MUST** comply with NESDIS specifications for HDR GOES sections 2.1.2, 2.1.3, 2.1.4, and 2.1.5. The HDR 300 bps transmitter clock **MUST** meet the requirements of the 1200bps transmitter.

11. Programming Interface, Firmware and Software

1. The firmware that is resident in the DATA LOGGER **MUST** be upgradeable by PC using a method that does not require replacement of DATA LOGGER internal components.
1. All interaction with DATA LOGGER programs **MUST** be possible using a PC.
1. When using a PC, upload and download of parameter set-up sensor management, data acquisition and retrieval **SHALL** be accomplished through menus or pop up windows.
1. Where applicable input of numeric information **SHALL** be in engineering units.
2. The DATA LOGGER logger **SHALL** revert to previously stored configuration if abnormal exit from configuration routines occurs.

12. Sensor Management

- Level 1

The DATA LOGGER **SHALL** be programmable with respect to how data from a sensor is acquired and processed. The DATA LOGGER **SHALL** have the following features as a minimum:

1. Capability to create, edit or delete sensor set-ups.
2. Data Acquisition:
    1. Start time for data acquisition variable by sensor.
    2. Acquisition frequency programmable from 1 per second to 1 per day.
3. Data Logging:
    1. Log data with date and time stamp.
    2. Logging frequency programmable from 1 per minute to 1 per day.
    3. Ability to turn log on and off.
4. Maximum and/or minimum sensed values:
    1. Determine values, programmable from 1 per minute to 1 per day.
    2. Log value with date and time stamp of actual acquisition time (to the nearest minute) of the occurrence of max and/or min.
5. Alphanumeric sensor labelling (2 characters minimum length).
6. Individual sensors independently programmable.
7. Position of decimal point variable by sensor.
8. Activation of a sensor (on/off designation).
9. Data download from user selectable date.
10. Provide for logging on PC or DATA LOGGER continuous live readings for user selectable sensors with date, time stamp, and labels.
11. Data output via land-line **MUST** be individually selectable.
12. Direct access (transparent mode) to SDI-12 bus.
13. Capability of logging a minimum of 10 distinct parameters.
14. Easy input of conversion formulas for different sensors, i.e. temp. probes.

    The following range of math instructions **SHALL** exist:

    Z = F Z = X
    add subtract multiply divide
    sqrt ln(X) e^X x^y π (Pi)
    abs frac int mod
    sine cosine tangent
    minimum fifth order polynomial
    block move ,sliding block move
    min. max. avg
    spatial max spatial min spatial average
    mathematical functions are executed using the normal mathematical precedence.
    a minimum of 10 user defined equations of up to 120 characters per equation.

    Note: This does not exclude other math instructions

Level 2

as above plus **MUST** have the following features as minimum.

1. Logging frequency programmable from 1 per second to 1 per day.
2. Maximum and/or minimum sensed values:

    determine values, programmable from 1 per second to 1 per day;

    log value with date and time stamp of actual acquisition time (to the nearest second) of the occurrence of max and/or min.

3. Ability to acquire sensed data in time ordered, event ordered and gradient intervals.
4. Programmable alarm function (gradient and level). **SHALL** also have the capability of triggering a function (e.g. reading another sensor);
5. Data output via telemetry **MUST** be selectable
    1. by parameter.
    2. by occurrence (i.e. data collected at 15 minute intervals, only hourly values transmitted).
6. Ability to run the logger in standard time with an option to offset for Co-ordinated Universal Time (UTC).
7. Capability of logging a minimum of 15 distinct parameters.
8. User selectable warm-up time for a duration from one second to fifteen minutes for data acquisition by sensor parameter.

13. Data Acquisition Integrity Routines

1. The DATA LOGGER **MUST** permit, by means of the PC, the initiation of sensor sampling test cycle and the presentation of these results for analysis.
1. Acquisition, archiving routines **SHALL** not be interrupted during communications to logger or sensor (via logger) via direct connect PC or telephone communications systems.

14. Data Storage

1. The DATA LOGGER **MUST** have a minimum of 200 days data storage for:
    1. three (3) environmental parameters logged hourly, with one maximum and one minimum per day, based on 5 minute samples of the sensor.
    2. maintenance parameters logged once per day.
    3. all of above complete with date and time stamp and data labels.
2. There **MUST** be a warning about potential memory erasure/data loss if user actions could result in such an occurrence.
3. Data overwrite when memory is full **MUST** be user selectable (overwrite as default).

15. Data Handling

- Level 1

1. Logger **MUST** accept and store input data that may have up to 5 significant digits, with the position of the decimal point variable by sensor.
1. All intermediate calculations **MUST** provide results equivalent to 32-bit long integer architecture as a minimum, with a resolution at least one digit greater than the input data.
1. Data download :
    1. The data that is resident in the DATA LOGGER **MUST** be downloadable by direct connect to a PC.
    2. For data logged as per Data Storage item 2.2.14.1 the elapsed time of download **SHALL** not exceed ten minutes from start of download to resultant ASCII file stored on PC.
    3. The resultant output **MUST** be in tabular or sequential ASCII format as described in Appendix A.2.
    4. The output **MUST** allow up to 7 digits as a minimum, including decimal point and sign, with the position of the decimal point variable by sensor.
1. Data Presentation:
    1. **MUST** be in tabular or sequential ASCII format as described in Appendix A.2.
    2. **MUST** provide time series graphing of downloaded data as per Data Storage item 2.2.14.1:
        1. minimum of 2 parameters simultaneously.
        2. user selectable parameter versus time.
        3. user selectable scale for individual parameters.
        4. user selectable time interval by date.

- Level 2

.as above plus:

1. replace item 2.2.15 level 1.2 above with: All intermediate calculations **MUST** provide results equivalent to 32-bit IEEE 4-byte Real (Single Precision, Floating Point) as a minimum.
1. GOES satellite data (conventional data rate and high data rate) **MUST** be in ASCII format as described in Appendix A.3.

1. Data transmitted via GOES satellite (not including HDR transmissions) should be centred in the assigned transmission window. (examples 30 sec, 1 min, 2 min)

Appendix 2
Performance Specifications for Pressure Transducers

2.1 ENVIRONMENTAL SPECIFICATIONS - Pressure Transducer
(Referenced Military standards methodology will be used when testing for compliance is required)

1. Relative Humidity & Moisture	1. **MUST** withstand max. humidity 100% non condensing at 50°C & -40°C, min. humidity 3% at 50°C. 2. Casing **MUST** be water resistant.
2. Operating Temperatures	1. Non-Submersible equipment **SHALL** operate through an ambient temperature range of -40°C to +50°C, **SHALL** withstand temperatures from -60°C to +65°C and **MUST** automatically recommence normal operation when operating temperatures are achieved. 1. Submersible equipment **SHALL** operate through an ambient temperature range of -10°C to +50°C, **SHALL** withstand temperatures from -60°C to +65°C and **MUST** automatically recommence normal operation when operating temperatures are achieved. 2. Cables **SHALL** remain flexible at -40°C (**MUST** not be brittle) and **SHALL** not deteriorate at +65°C.
3. Thermal Shock, Transportation (Mechanical Shock and Storage)	1. Equipment **SHALL** withstand instantaneous induced thermal shock during transport of 70°C (-50°C to +20°C) and **SHALL** operate under thermal shock of 15°C/min. for 2 minutes (-20°C to +10°C). 2. Equipment **SHALL** operate after experiencing a series of mechanical shocks equivalent to 18 impact shocks of 15g consisting of 3 shocks in each direction (6 total) applied to each of 3 mutually perpendicular axes of the equipment. Military Standard 810E, 516.4 (14 July 1989)
4. Corrosion Protection	1. Corrosion resistant materials **SHALL** be used.
5. Vibration	1. Equipment **SHALL** withstand transportation vibrations of 10 – 50 Hz without being in a shipping container. Military Standard-167.
6. Sand & Dust	1. Sand and dust **MUST** not alter the operation of equipment.
7. Wind (for outdoor mounted components)	1. **MUST** withstand 5 second gusts up to 250 km/h and an average hourly wind speed of 160 km/h.
8. Ice Accretion (for outdoor mounted components)	1. Equipment **SHALL** operate under icing conditions of 50mm thickness and specific gravity of 0.9, at winds as specified above. Military Standard 810E, 521.1 (14 July 1989)
9. Solar Radiation (for outdoor mounted components)	1. Equipment and components **SHALL** operate: during periods of insolation intensity of 1022 W/m^2 : during periods of ultra violet intensity of 64.5 W/m^2 ;and withstand the effects of insolation intensity of 75.25 W/m^2. Military Standard 810E, 505.3 (July 14, 1989)

2.2 TECHNICAL SPECIFICATIONS Pressure Transducer

1. Power Requirements	1. Operating voltage **SHALL** be 11 VDC to 15 VDC with possible over voltage levels up to 20 VDC. 1. Minimum cut-off voltage **MUST** be 10.75 VDC. 2. Power consumption **SHALL** not exceed 30 mAmps active and 10 mAmps quiescent. 3. The bid **MUST** state in tabular format, the power requirements of the instrument for all modes of operation and how over under and reverse voltage conditions will be accommodated. 4. Primary power **SHALL** be provided via the SDI-12 communication cable.
2. Electromagnetic Interference	1. Equipment (non-submersible) **SHALL** meet class A3 requirements of MIL-STD-461D for radiated emissions (RE102) and for radiated susceptibility (RS103).
3. Lightning Protection	1. The pressure transducer **MUST** withstand repeated power transients resulting from near lightning strikes.
4. Surge Protection	1. Equipment **SHALL** conform to surge protection standards as detailed in ANSI Standard C62.41 “Surge Protection in Low Voltage AC Power Circuits”, Class B.
5. Over Voltage and Current Protection	1. Equipment **SHALL** not be affected by transient voltage and current originating from the power supply or other sources.
6. Memory Protection and EPROM Memory life write expectancy	1. Memory related to set-up parameters **SHALL** be protected against loss: during primary power interruption; and as power returns to normal operational levels. 2. The write to EPROM memory **SHALL** operate properly for a minimum of 10 years based on measurements at 5 minute intervals and 40 parameter changes per year.
7. Conversion	1. Pressure-to-water level **MUST** be converted to metric output (resolution to 0.001m.). The value **SHALL** define the water level with respect to pre-determined reference. 1. All intermediate calculations **MUST** provide results equivalent to 32-bit long integer architecture as a minimum, with a resolution at least one digit greater than the input data. 2. Conversion units **SHALL** be user programmable. 3. SDI-12 commands **SHALL** be used to set slope and offset.
8. Range	1. The normal operating range **SHALL** be within 0 to 10 metres. 1. The pressure transducer **SHALL** be protected against over-pressure by twice the range.
9. Response Time	1. The unit **MUST** measure a water level change up to a maximum rate of 1 metre per 10 minutes while maintaining measurement accuracy.
10. Accuracy	1. The accuracy **MUST** be within 0.1% full scale over specified temperature and humidity range.
11. Drift	1. Drift **MUST** be less than 0.05% of full scale over a 6 month period.
12. Output Data	1. The output data **MUST** be presented in accordance with SDI-12 protocol. 1. The stage output **MUST** consist of instantaneous and time integrated values. 2. Units of data output **MUST** be in metres.

13. Configuration

1. All sensor configurations **MUST** be carried out via the SDI-12 interface.
1. The integration period **MUST** be user selectable ranging from 5 to 120 seconds.
2. Number of samples and sampling period **MUST** be user configurable.

14. Calibration

1. The sensor **SHALL** be delivered fully calibrated over stated operating pressure and temperature range.
1. A calibration table **MUST** be supplied with the pressure transducer.
2. A recommended time interval to the next required calibration **MUST** be supplied with the pressure transducer.

15. Connectors

1. All connectors to the pressure transducer **SHALL** be equipped with a positive locking mechanism, which will prevent inadvertent separation of the plug and socket.
1. Except for terminal strips, all connectors containing a live wire end **MUST** be female (Non-submersible only).
2. Insulation displacement connectors **SHALL** conform to the requirements of MIL-C-83503A. (Non-submersible only).

Non-Submersible Pressure Transducers.

1. The pipe fitting for the gas purge orifice line **MUST** be female.
2. Fittings **MUST** accept 9.525 mm (0.375 inch) outside diameter tubing .
3. The internal electronic components of the instrument **MUST** be protected against moisture leaks emanating from the compressed gas line tubing or other piping connected with the pressure sensing system.

Submersible Pressure Transducers

1. The sensor and/or electronics **MUST** be protected against damage due to water infiltration of the submerged unit.
1. The reference-pressure vent tube **SHALL** be separate from the SDI-12 communication cable and a dry line capability should be provided to ensure that measurement results are not influenced by moisture in the vent.
3. A connector **MUST** be supplied for the PVC orifice line tubing of 9.525 mm (0.375 inches) outside diameter.
1. The SDI-12 connector on the unit **MUST** be fitted with a positive locking device and **MUST** be waterproof to a minimum of twice the rated pressure range of the instrument .

16. Cables

1. For the non-submersible a minimum 1.5 metre SDI-12 communication cable with appropriate connector **MUST** be provided to connect transducer units to the logger. (not required if permanently integrated as a single unit).
2. For the submersible a pig-tail minimum 0.5 metre length **SHALL** be provided.
3. The transducer cables supplied should conform to the standard wiring format for external SDI-12 connectivity:
   . white=data, --- red=positive, --- black=negative

17. Dimensions

1. The size of the non-submersible pressure transducer unit **MUST** not exceed 25 cm long x 30 cm wide x 25 cm high.

Appendix 3
Performance Specifications for Shaft Encoders

2.1 ENVIRONMENTAL SPECIFICATIONS - Shaft Encoder (Referenced Military standards methodology will be used when testing for compliance is required)	
1. Relative Humidity & Moisture	1. **MUST** withstand max. humidity 100% non condensing at 50°C & -40°C, min. humidity 3% at 50°C. 2. Casing **MUST** be water resistant.
2. Operating Temperatures	1. Equipment **SHALL** operate through an ambient temperature range of -40°C to +50°C, withstand temperatures from -60°C to +65°C and **MUST** automatically recommence normal operation when operating temperatures are achieved. 2. Cables **SHALL** remain flexible at -40°C (**MUST** not be brittle) and **SHALL** not deteriorate at +65°C.
3. Thermal Shock, Transportation (Mechanical Shock and Storage)	1. Equipment **SHALL** withstand instantaneous induced thermal shock during transport of 70°C (-50°C to +20°C) and **SHALL** operate under thermal shock of 15°C/min. for 2 minutes (-20°C to +10°C). 2. Equipment **SHALL** operate after experiencing a series of mechanical shocks equivalent to 18 impact shocks of 15g consisting of 3 shocks in each direction (6 total) applied to each of 3 mutually perpendicular axes of the equipment. Military Standard 810E, 516.4 (14 July 1989)
4. Corrosion Protection	1. Corrosion resistant materials **SHALL** be used.
5. Vibration	1. Equipment **SHALL** withstand transportation vibrations 10 – 50 Hz without being in a shipping container. Military Standard-167.
6. Sand & Dust	1. Sand and dust **MUST** not alter the operation of equipment.
7. Wind (for outdoor mounted components)	1. **MUST** withstand 5 second gusts up to 250 km/h and an average hourly wind speed of 160 km/h.
8. Ice Accretion (for outdoor mounted components)	1. Equipment **SHALL** operate under icing conditions of 50mm thickness and specific gravity of 0.9, at winds as specified above. Military Standard 810E, 521.1 (14 July 1989)
9. Solar Radiation (for outdoor mounted components)	1. Equipment and components **SHALL**: operate during periods of insolation intensity of 1022 $W/m^{2;}$ and ultra violet intensity of 64.5 $W/m^{2;}$ and withstand the effects of insolation intensity of 75.25 W/m^2. Military Standard 810E, 505.3 (July 14, 1989)

2.2 TECHNICAL SPECIFICATIONS - Shaft Encoder

1. Power Requirements	1. Operating voltage **SHALL** be 11 VDC to 15 VDC with possible over voltage levels up to 20 VDC. 2. Minimum cut-off voltage **SHALL** be 10.75 VDC. 3. Power consumption **SHALL** not exceed 30 m Amps active and 10 m Amps quiescent. 4. Power requirements of the instrument **MUST** be stated for all modes of operation and how over, under and reverse voltage conditions will be accommodated. 5. Backup batteries **MUST** support easy field replacement- not soldered in place 6. Primary power **SHALL** be provided via the SDI-12 communication cable.
2. Electromagnetic Interference	1. Equipment **SHALL** meet class A3 requirements of MIL-STD-461D for radiated emissions (RE102) and for radiated susceptibility (RS103).
3. Lightning Protection	1. The shaft encoder **MUST** withstand repeated power transients resulting from near lightning strikes.
4. Surge Protection	1. Equipment **SHALL** conform to surge protection standards as detailed in ANSI standard C62.41 “Surge Protection in Low Voltage AC Power Circuits”, Class B.
5. Transient Voltage and Current	1. Equipment **SHALL** not be affected by transient voltage and current originating from the power supply or other sources.
6. Memory Protection and EPROM Memory life write expectancy	1. Memory related to set-up parameters **SHALL** be protected against loss during primary power interruption and as power returns to normal operational levels. 2. The write to EPROM memory **SHALL** operate properly for a minimum of 10 years based on measurements at 5 minute intervals and 40 parameter changes per year.
7. Shaft Diameter	1. The outside diameter of the “quarter inch” shaft (within the following tolerance) **MUST** fit in the assembly hub. (metric units - cm - tolerance 0.0000 to -0.0005) (Imperial units - inches - tolerance 0.0000 to -0.0002)
8. Rotation	1. The input shaft **MUST** be capable of rotating about its longitudinal axis in both the clockwise and counter-clockwise directions. The instrument **MUST** be capable of tracking a shaft rotation equivalent to 2.5 revolutions per second in either direction.
9. Torque	1. The starting torque of the input shaft **MUST** not exceed 3.53 mN·m (0.5 ounce-inch) at temperatures from 10°C to 40°C and **SHALL** not exceed 7.06 mN·m (1.0 ounce-inch) at temperature from -40°C to 55°C. 2. Running torque **SHALL** not exceed the starting torque at speeds up to 1 revolution per second.
10. Conversion	1. Unless already converted, the unit **MUST** convert the rotation to metres defaulted so that it counts 0.375 metres per rotation. The value **SHALL** define the instantaneous position of the shaft in respect to pre-determined reference. 2. All intermediate calculations **MUST** provide results equivalent to 32-bit long integer architecture as a minimum, with a resolution at least one digit greater than the input data 3. SDI-12 commands **SHALL** be used to set slope and offset.

11. Range	1. The range **MUST** be within -30 m to +30 m.
12. Resolution	1. The resolution **MUST** be equal to, or better than 0.001 m for one revolution of the shaft encoder using a 0.375 m circumference wheel pulley float. 2. The accuracy of the shaft rotation definition **MUST** be plus or minus 0.001 m.
13. Output Data	1. The output data **MUST** be presented in accordance with SDI-12 protocol. 2. The shaft encoder **MUST** have the capability of providing readings in response to requests from the logger at frequencies from 1 per second to 1 per day. 3. Units of data output **MUST** be in metres.
14. Configuration	1. Configuration **MUST** be carried out via the SDI-12 interface. 2. The shaft encoder **MUST** have the capability of providing instantaneous, maximum and minimum readings. 3. Number of samples and sampling period **MUST** be user configurable.
15. Float Pulley Assembly	The float pulley assembly hub **MUST** be designed to provide electrical isolation between the pulley and the shaft. The 0.375 m circumference pulley **MUST** have a centered “half inch” bore (within the following tolerance) to fit over the pulley assembly hub. (metric units - cm - tolerance 0.000 to +0.003) (Imperial units - inches - tolerance 0.000 to -0.001) The pulley assembly hub **MUST** have a “half inch” outer diameter end (within the following tolerance) to fit into the bore of the 0.375 m circumference pulley. (metric units - cm - tolerance 0.000 to -0.003) (Imperial units - inches - tolerance 0.000 to -0.001) The pulley assembly hub **MUST** have a centered bore of a “quarter inch” inner diameter (within the following tolerance) to fit over the encoder quarter inch shaft. (metric units - cm - tolerance 0.000 to +0.0005) (Imperial units - inches - tolerance 0.000 to +0.0002)
16. Connectors	1. A military, or suitable environmental equivalent, connector **MUST** be provided with the unit to facilitate access to its output interface. 2. All connectors for the shaft encoder **SHALL** be two-part connectors, equipped with a positive locking mechanism which will prevent inadvertent separation of the plug and socket. 3. Except for terminal strips, all connectors, containing a live wire end, **MUST** be female. 4. Insulation displacement connectors **SHALL** conform with the requirements of MIL-C-83503A. 5. The cables supplied should conform to the standard wiring format for external SDI-12 connectivity : white = data, --- red = positive, --- black = negative,
17. Cables	1. A minimum 1.5 metre long SDI-12 communication cable **MUST** be supplied to connect shaft encoder to the logger.
18. Enclosure	1. The enclosure **SHALL** be configured for mounting on a flat horizontal surface (i.e. table or shelf) and **SHALL** be high enough to allow a minimum clearance of 0.010m from the 0.375m circumference pulley float to operate. 2. Mounting configuration that is capable of maintaining the instrument fixed in position under the load of counter weight and float **SHALL** be provided for fastening the shaft encoder to a table or shelf.
19. Dimensions	1. The maximum size of the shaft encoder **SHALL** not exceed 20 cm long x 20 cm wide x 20 cm high.

Appendix 4
Example of Test Procedure for Data Logger

Qualification test procedures-...

Appendix 5
Example Reports on Instrument Testing and Comparison

Flowtracker test report final ...

PerfectSensorArticle.doc (257 ...

Many other examples exist in the USGS HIF database.