

**ACCEPTANCE PROTOCOL FOR PROCUREMENT OF DWLRs (GW)**

# Acceptance Protocol

## 1. General

The delivery of bid goods/equipment and software should be in accordance with the order placed with the Supplier. To formalise the process of delivery an Acceptance Protocol is prescribed.

The Acceptance Protocol shall serve as a formal guidance during delivery of the DWLRs. Its primary goals are twofold.

1. Ascertain the delivery and completeness of all ordered products and related documents.
2. Check the functioning of the equipment and software in a formal way against the specifications by application of Acceptance Tests. The tests also verify the accuracy and stability of the equipment.

The Acceptance Protocol shall be executed in close co-operation between the Supplier and the Client.

Products shall be accepted only if they meet the requirements and are functioning in compliance with the technical specifications, and the related documents are complete and correct. Defective products and any other discrepancies shall have to be replaced/resolved, within a pre-defined time frame.

## 2. Documents

The following documents shall accompany the delivery of the instruments and software:

1. Administrative and QA documents
2. Test and calibration documents
3. Manuals and Guidelines

All documents shall have identification and references to subject or instrument, date, time, location and officer in charge.

The Acceptance Report lays down the findings and observations during the execution of the Acceptance Protocol and is a formal document to record the acceptance or rejection of any item as covered in the Bid document. Any flaws or findings are to be reported. The forms and checklists filled out during the execution of the Acceptance Protocol are to be enclosed with the Acceptance Report. The Supplier receives a signed copy of the Acceptance Report, which the Supplier can use as proof that the items listed in the report were accepted.

The content of the various documents shall be as follows:

### 2.1 Administrative and QA documents

These Quality Assurance (QA) documents shall include:

- Production documents associated with the instruments.
- Type codes, serial numbers and other identification data on, possibly externally procured, sensors and major assemblies, to clearly demarcate the sensors/major assemblies associated with each DWLR.
- Shipping documents indicating instrument/product type, serial number, measuring range, cable length and other similar data.

### 2.2 Test and calibration documents

A comprehensive Method Statement on the applied calibration and in-factory test procedures shall accompany the bid document. The Method Statement defines the test and calibration methods applied on the instruments and the components thereof. The Method Statement shall also include, for each calibrated product, an audit trail to national standards on all instruments and facilities used for testing

and calibration. The Audit Trail Report shall associate the calibration of the reference instruments and test equipment to the national calibration standards.

If the Supplier or Manufacturer is not in a position to deliver an Audit Trail Report to the national standards, the Manufacturer shall explain what the quality standards are and how they are maintained and monitored.

Conditions during calibration, such as room and/or instrument temperature, equipment and facilities used, shall be included in the calibration and test documents.

The test and calibration documents shall contain the data generated during calibration and testing, including:

- Calibration data supplied by the Manufacturer of pressure sensor
- Calibration and test data of the datalogger electronics
- Calibration data on overall DWLR calibration, i.e. comprising both pressure sensor and electronics. A table listing applied reference pressures versus instrument readings is to be delivered for each sensor and instrument. Furthermore, that table shall also show the test conditions during calibration
- Data on hysteresis test
- Data on temperature tests
- Data on zero stability test
- Data on scale stability test
- Humidity test, in particular for vented gauge pressure sensors
- Temperature cycling of sensor and electronics
- Spray test on enclosure(s), connectors and cables

### **2.3 Manuals and Guidelines**

The manuals shall meet the requirements on style and clarity, completeness, preciseness, detail and accessibility. This includes:

- System manual,
- Operation, Maintenance and Service manuals,
- Observation guideline, and
- Training handouts.

## **3. Acceptance Tests**

### **3.1 General**

Qualified engineers under responsibility of a test manager shall execute the Acceptance Tests. The progress of the Acceptance Tests is monitored and supervised by the Client and/or his authorised representative. The Client may have any tests redone or additional tests executed as he deems required based on the results of previous tests conducted. The Client's test party has the right of access to any instrument and may request any data or information at any time. The Supplier has the obligation to deliver requested information without delay; i.e. collected test data and documents must be available at the test site.

It is important that all activities (what, when, where, who, which instrument, etc.) are annotated and uniquely linked to the individual instruments.

The Acceptance Tests mainly comprise three levels viz.:

#### *Functional Tests*

The Functional Tests shall verify the proper functioning of the instruments and the associated software. Primary goal is to verify that the instrument performs its functions according to the bid specifications.

### *Accuracy Tests*

The Accuracy Tests shall verify that each individual instrument is functional and operates according to the bid specifications. A number of relatively simple accuracy tests are routinely exercised on the instruments.

### *Overall Test*

The main purpose of the Overall Test is to verify the common features that are identical to all the instruments in a series. Typical components of the Overall Test are: in-built software functions, materials of the instrument, cables, connectors, etc. Further tests include battery and memory autonomy, details of sensor specifications like temperature effects, hysteresis, long term stability etc.

The above tests can be executed at any one of the following locations:

- Premises of the Manufacturer/Supplier;
- Premises of the Client;
- Independent organisation.

The charges for testing at the Manufacturer's/Supplier's premises shall be borne by the Manufacturer/Supplier. The Client may at his cost be present during the performances of the tests. If the tests are executed at the Client's premises, the charge for testing shall be borne by the Client and the Supplier shall be responsible for conducting the tests. The bidder in his bid shall indicate the independent organisation and the charges for testing. The Client reserves the right to accept the independent organisation and its charges or get the tests done by any other agencies. However, the Supplier shall be permitted the opportunity to be present at these tests.

The details of these tests are as follows.

## **3.2 Functional Tests**

The Functional Tests include:

- visual inspection, and
- user tests.

### **3.2.1 Visual Inspection**

Visual inspection includes the following activities.

- All items are visually checked for damage, e.g. on cables, sensor and housing.
- Availability of non-removable identification codes and specifications are verified, e.g. serial number, type identification, manufacturer and measuring range.
- Cables have to be marked as well: each cable is to have an identification code and name.
- Cable connectors shall have their ends marked suitably to indicate the device to which it is to be connected, e.g. PC, HHT, Power Supply etc. Suitable precaution shall be taken so that the connectors are not connected to wrong terminals, i.e. it shall be impossible to connect a power cable to a communication bulkhead socket.

### **3.2.2 User tests**

All instruments have to be identical except for measuring range, cable length, identification code and similar aspects. Consequently there is no need to check the functionality of all systems. It is assumed that the functional compliance with the specifications is tested under the Overall Tests. The objective of the user test is to detect any malfunction and/or defect. From practical point of view, the user tests can be coupled with other test, e.g. the stability tests.

Basic functions to be tested are:

- Pre-deployment preparation, e.g. setting of clock, erasing of memory, setting data logging parameters, entry of identification data
- Facilities for execution of on-site functional checks

- Data retrieval and data transfer to PC
- Conversion of retrieved data into ASCII table for application by user's software
- Battery status and voltage
- Simple output test by observing pressure reading while the sensor is immersed in a bucket filled with water

### 3.3 Accuracy Tests

The Accuracy tests include:

- accuracy tests on clock, and
- accuracy tests on pressure measurement

#### 3.3.1 Accuracy tests on clock

The clock of the datalogger shall be carefully checked against national time, e.g. taking the radio broadcast time beeps as a reference. The datalogger clock is set precisely and checked at the start of the individual tests and upon instrument and/or data retrieval. In between, the clock should not be re-adjusted.

The clock test shall cover at least 3 days to get sufficient time resolution. The reference clock, e.g. a watch, must be carefully tuned against national time prior to and during the tests. The clock drift, converted to seconds per month (31 days) shall comply with the defined specifications. This test method makes use of the specified time resolution of 1 s.

#### 3.3.2 Accuracy tests on pressure measurement

The accuracy test on the pressure sensor is an overall accuracy test covering both the pressure and electronics systems. The pressure tests are to be executed against accurately known reference pressure(s). Pressure can be generated from compressed air (gas) or by submerging the sensor to known depths in water.

Reference pressure may be created via a precision pressure reduction valve from a source of compressed air. A high precision sensor like a Paroscientific DigiQuartz pressure sensor or a Dead Weight Tester can be implemented to quantify the applied pressure. Pressure should be measured in kPa (or mbar).

When applying the immersion method it is much more difficult to check the instruments because water density affects the reading. Moreover, it is not simple to establish the exact depth of sensor immersion. And especially in narrow wells, while immersing a pressure sensor on its cable into a well, the waterlevel will rise due to the additional volume of the immersed pressure sensor and cable. The water level will gradually fall again, when the well level adjusts again to equilibrium with the ground water level. In order to achieve a high accuracy these effects have to be assessed.

During the tests, temperature and barometric air-pressure should be accurately logged against time, preferably by automatic instruments or otherwise by half hourly manual reading, i.e. 48 times a day. In particular for the zero stability tests, logging by digital instruments makes subsequent computerised data processing more effective. Data retrieved from chart records and manual readings must be keyed into a computer file during the tests. The data entry shall not be delayed beyond execution of the stability tests to ascertain a proper check during the tests and to allow for quick verification of the results and feedback, if required.

The pressure sensor tests include:

1. ***Zero stability test***
2. ***Scale test***
3. ***Scale stability test***

The pressure sensor tests shall focus on temperature effects on zero, scale and cable length, and in addition to that establish quantitative data on drift of zero, scale and creep of cable length.

### **Zero stability test**

During the zero-test the instruments are in logging mode, say at an interval of 30 minutes, and shall be kept in a separate room where they will not be touched for at least 3 days. The instruments must be dry, i.e. not in a bucket of water, to exclude any water effect on the sensor, and hence, the instrument reading is expected to be 0.0.

Under this test, each instrument will record its short term zero drift and inherently the effectiveness of the air-pressure compensation method. During the zero-test, the instruments shall be in the same and constant position, vertical or horizontal. The room temperature shall vary over 5 °C or more, e.g. due to daily temperature fluctuation, this to assess temperature effects on the instrument reading. This requirement may affect the choice of venue for the zero-tests. To avoid any adverse temperature strain, no direct sunlight shall fall on the instruments. At the end of the test, the collected data are offloaded from the datalogger memory and analysed for zero stability. As the instruments are kept in air and are not touched, the reading shall be stable and not change over time, that is not beyond permissible limits.

Room temperature is to be logged against time, preferably by digital method. In case the DWLR has a built-in temperature sensor, that sensor may be used for temperature logging. The pressure sensors shall not be tested in an air-conditioned room for several reasons. First, temperature fluctuations may be so rapid that the sensor temperature compensation scheme may not be able to cope with it. Moreover, rapid air-pressure fluctuations may not be handled properly by the air-vent system and/or the pressure measurement method. This is to be understood from the perspective that the instruments are designed to operate in wells where changes occur but not rapidly. One or more fans may be operated continuously to minimise temperature gradient across the test room.

To test the creep and elongation of the electrical cum suspension cable some vertical open space is required, e.g. a stairwell can be used for this purpose. However, it is important that the cable is protected against touch to avoid interference with the measurements. The cable is loaded with some weight to emulate the weight of cable and sensor. The length of cable under tests shall be as long as possible, i.e. 10 m or more, to get the best accuracy of the tests. The lowest point is suspended to about 0.15 m above the floor. The gap between lowest point and floor is monitored against time. Initially readings are taken every 30 minutes for 12 hours, subsequently the reading interval may be increased to 6 hours. The cable test shall be executed during 7 days. Resolution of measurement should be 1 mm or better. The result is to be presented in mm length change per meter suspended cable length. Only one cable is to be tested.

### **Scale test**

A precisely known pressure is applied on the instrument and the instrument reading is taken. The instrument reading is converted into level or pressure whatever is applicable. The calculated value is compared with the applied value; the difference is regarded as the FS error. In case the specifications of the applied pressure sensor may give reason to doubt the instrument's linearity, then a midscale test is to be executed as well.

### **Scale stability test**

Scale stability is tested by subjecting the instrument to the full-scale pressure for at least 24 hours. During the test, the applied pressure/level is to be accurately monitored by taking reference readings either by a reference logger of high accuracy or by manual readings. The accuracy and resolution of the reference measurement must be 1 mm water column or 0.01 kPa (0.1 mbar).

## **3.4 Overall Test**

Part of the Overall Test is also covered under the Functional Tests and Accuracy Tests. The Overall Test comprises tests on:

- autonomy
- fitness for environment
- functionality

- calibration
- stability
- reproducibility, and
- main power failure

Details of the various tests are as follows.

### **3.4.1 Autonomy**

Two autonomy tests shall be conducted:

- battery capacity versus the power consumption per measurement, and
- memory capacity

#### *Battery autonomy test*

To execute the test, the instrument is set to a fast data collection interval and the capacity, i.e. the number of samples, is established by a continuous process of data collection until the batteries are depleted. The test shall be executed on new batteries. In this context, the batteries are deemed depleted when the instrument stops functioning because the battery voltage watch-dog function detects a too low battery voltage or the normal operation of the instrument stops.

#### *Memory capacity verification*

The memory is filled at the highest data-recording rate and the volume of collected data are verified against the bid specification. This test could be combined with the battery autonomy test and the samples are taken at a high rate to minimise the test duration.

### **3.4.2 Fitness for environment**

Connectors, cable glands, cables and housing must be suitable for the environment of operation, be it submersed, in a well or above the ground. Water ingress can be assessed by visual inspection and / or by insulation measurement. Visual inspection may only reveal ingress of a significant amount of water. The insulation measurement is more sensitive, especially for cables, connectors and encapsulated electronics, but requires specialised equipment.

- The above-surface components have to be compatible with IP65 standard and shall be tested accordingly by exposing them to a heavy shower for 3 minutes. Subsequently the ingress of water is assessed by opening of the instrument and connectors.
- The submersible components must comply with IP68 standards. To verify this, the instrument shall be suspended in a well for at least one week, to a maximum depth, without affecting the calibration of the pressure sensor and not exceeding 2 times the rated measuring range. Although most pressure sensors can withstand considerably more than 2 times the rated measuring range, there is no need to exceed this. Prior to this test, the zero and scale of the sensor have to be established and verified again upon recovery.

### **3.4.3 Functionality**

- Functionality has to be verified for all requirements for operation of the DWLR and DRS with reference to the bid specifications and the instrument specifications as given by the Manufacturer. Missing functionality shall be reported.
- All (software) functions as stated in the instrument manual(s) and the instrument specifications are tested for correct functioning. Any detected flaws are reported which shall be repaired/rectified by the Manufacturer/Supplier within seven days.

### **3.4.4 Calibration**

The instrument calibration is checked for compliance with the bid specifications. In particular accuracy, stability, linearity, hysteresis and reproducibility are verified.

The scale or sensitivity of the complete instrument, including sensor and electronics, is to be checked for at least 11 pressures, equally distributed over the full measuring range. Furthermore, the calibration data

as delivered with the instrument are verified for accuracy and consistency with data obtained from the calibration tests. The calibration may be executed by application of accurately known air-pressure or by immersion in a well. The temperature effects on the calibration should also be verified at low, mid and maximum range temperatures.

**Note:** Prior to execution of immersion tests, the effective position of the sensor membrane relative to the sensor housing is to be assessed and measured, e.g. by execution of a bucket experiment. In this experiment, the sensor is partly immersed in a water filled bucket to a depth where the related reading has changed by several centimetres, relative to the 'in-air' reading. During the test, the position of the water surface on the sensor's body shall be observed and marked accordingly. The 'effective-sensor-zero' lies below the water surface during the test. The position of the effective-sensor-zero is below the above mentioned water-surface mark by the equivalent of the sensor reading expressed in centimetres. The effective-sensor-zero may be close to the sensor membrane but not necessarily coincides with it.

### **3.4.5 Stability**

Stability related to the DWLR is defined as a variation over time of the instrument specifications, whereas the circumstances and pressure do not vary. Parameters to be checked are:

- zero: offset stability
- scale: full scale stability
- cable: length (extension/contraction) and creep stability

The methods to assess these stability factors are explained under the section on Accuracy Tests.

### **3.4.6 Reproducibility**

The sensor reading in air is annotated, subsequently the sensor is immersed to the rated measuring depth, and a stable reading is collected. Then the sensor is recovered to the surface and again a stable reading is taken. This process is repeated 5 times and results are duly annotated. It is important that during the complete test the instrument is kept in the same, vertical position.

### **3.4.7 Main power failure**

Some instruments operate on replaceable batteries or even external power and have a built-in back-up facility, usually based on a Lithium battery. It is quite possible that on some instruments the external power supply or the replaceable batteries fail because of total depletion, disconnection, defect on the cable or connector etc. In such an event, the instrument must retain its clock, its program setting and most importantly all the collected data.

The Functional Tests are executed in conjunction with the stability test. Upon finalising these tests and after successful retrieval of all test data the power is disconnected by removing the main power batteries and/or disconnecting the power cable. The instrument is to be left in that state for at least 24 hours. Then the power shall be connected again and clock, program settings and recorded data are checked for availability and correctness.

Instruments with entirely built-in factory replaceable batteries cannot be tested in this way. In such case, the Manufacturer shall provide a technical description of the method applied to avoid loss of clock, program and collected data.

## **4. Test Execution**

Two test programmes are to be executed:

- All Units Test Programme
- Single Unit Test Programme

Prior to execution of the tests, a detailed test script has to be drafted and agreed upon. The test script shall define:

- test sequence.
- the test conditions and requirements for each test.
- place of the test.
- person(s) responsible for conducting the tests.
- reporting requirements.
- handling failures and problems.

#### **4.1 All Units Test Programme**

The All Units Test Programme aims to identify the malfunctioning instruments and those not compliant with the bid specifications. The Functional Tests, the Clock Accuracy Test and the Zero Stability Test must be executed on each instrument. The design of the tests shall be selective and practical and enable execution with simple means, preferably at the Client's premises.

#### **4.2 Single Unit Test Programme**

A full system shall be tested, that is: pressure sensor, electronics, cable, power supply, DRS, software and manuals. The Single Unit Test Programme is a combination of the Functional Tests, the Accuracy Tests and the Overall Test. The Client shall randomly select an instrument for testing from the instruments delivered. The Single Unit Test Programme can only be started after verification that all documents related to the order/delivery, including manuals, calibration data, QA data etc., are delivered to the Client. Any other unit, for which doubts arise on its compliance with the bid specifications, shall also be tested on the client's request.

Failing to pass the Single Unit Test Programme results in rejection of the entire delivery until the defective units have been repaired to meet the technical specifications, and such to the satisfaction of the Client.

### **5. Evaluation of test results**

The test results have to be evaluated and results and conclusion shall be reported. Instruments that do not meet the bid specifications, shall be replaced by properly functioning and satisfactorily tested instruments.

### **6. Post acceptance performance monitoring**

After installation and field deployment the instrument performance shall be continuously monitored by taking manual observations, initially at a relatively high rate, e.g. every 3 hours, gradually migrating towards the normal monitoring interval. The level comparisons are required for reference and validation purposes. Manual observations and automatic readings shall be taken at short intervals after each other, in practice the time difference shall be kept to less than 15 minutes. The primary criterion though, is that the manual reading shall be taken before the water level changes more than 1 mm.

Other checks are on functioning of the internal clock, data recording and retrieval, battery discharge, siltation of the sensor, moisture ingress and any development of corrosion.

The tape used for taking the reference readings shall be of high accuracy, considerably better than the accuracy of the DWLR, only then the performance of the high accuracy instruments can be monitored. However, an accuracy of 1 mm over the full measuring range is enough. Only best quality tapes, e.g. the

electric types, come close to this requirement. The tapes shall be checked for accuracy against a precise reference, e.g. over 10 or 20 m on a single stretch. Verification by a standard ruler will not reveal to overall accuracy of a tape. The 'tape verification reference' could be prepared using high accuracy geodetic equipment. A long, straight corridor, or a quiet stretch of road, could accommodate the length reference marks, the accuracy should be 1 mm relative to the reference point (0.000 m).

## **7. Instrument History File**

For each instrument, an individual History File shall be opened and maintained. In the History File the full instrument history and all documents generated shall be stored. This also includes any changes, adaptations, repairs etc. made to the instruments. The products and results of the execution of the Acceptance Protocol shall be included in the Instrument History File.

Some document types and entries are listed below.

### **7.1 Instrument identification**

The instrument identification uniquely defines the instrument particulars.

- Make, vendor, service provider, date of manufacturing, date of delivery
- Instrument make, model and serial number
- Instrument configuration
- Measuring range
- Cable type, length
- Manual version
- Instrument status: e.g. working, under calibration, under repair

### **7.2 Functional, Accuracy and Over-all tests**

For each of the three test categories, a separate and unambiguous record shall be maintained. The test conditions and results shall be duly recorded. Obviously any failures or irregularities shall be annotated accurately and comprehensively, as well as the actions taken and their results.

At least the following data shall be recorded:

- Administrative data: what, when, where, who, which instrument and configuration
- List of tests
- Specifications for each test
- Results of each test
- Failures, actions, conclusions

### **7.3 Piezometer well definition**

The piezometer well definition is required in order to link the instrument readings to MSL and the hydro-geological properties of the well. The piezometer identification shall have sufficient detail to link it with the hydro-geological data recorded in the project database. The reference point on the piezometer well, as used for the level measurements, shall be unambiguously depicted and its height above MSL defined. The particulars of the local benchmark (name, location, and co-ordinates, height above MSL, etc.) shall be recorded for reference purposes. Following entries are indicative and not conclusive.

- Piezometer: District, name, location, co-ordinates, identification
- Photo
- Elevation relative to MSL
- Description of reference point particulars
- Identification of reference spot on piezometer well
- Local benchmark: district, location, identification, co-ordinates, height above MSL

## 7.4 Deployment

Another part of the history file covers the deployment: installation, servicing, maintenance, data retrieval etc. All facts shall be recorded, (what, when, where, who, which instrument and configuration). The suspended depth of the instrument relative to the reference point shall be annotated. Further, manual water level observations (when, who, level, reference) shall be taken regularly and verified with the instrument records. To allow for an accurate comparison, the time and other particulars of the manual observation shall be recorded. The manual observations shall coincide with the programmed automatic instrument readings. This shall be regularly repeated. Photos showing the mode of installation are very useful.

Some of the required particulars are:

- Suspension depth relative to the reference point on the piezometer well
- Recording interval
- Photos of the deployed instrument and piezometer well

Following two shall be repeated regularly:

- Manual observations, taken concurrently with the automatic measurements
- Observer, date and time of manual reading

The following entries are associated with any changes made to the instruments. Again, the ‘what, when, where, who, which instrument and configuration’ shall be recorded, for each event:

- Repairs: minor and major repairs and including change of silt filter or battery etc.
- Adaptations: e.g. replacement of EPROM, RTC clock speed adjustment
- Settings: these are the common operational settings such as recording interval, suspension depth and the like.
- Calibration: most likely calibration is executed in a special workshop. Obviously calibration is a major event and has to be recorded and documented accurately and comprehensively. This implies also the method of calibration, reference instruments used (and including a paper trail to national standards or other proof of calibration cum accuracy), conditions during calibration, officers in charge etc.