Quality Assurance

TRT barrel module acceptance tests

Abstract

This document presents a complete list of acceptance tests and criteria for TRT barrel modules performed at the assembly sites and during the acceptance process at CERN. It also provides a information on the content of the electronic passports, namely the production, gain mapping and acceptance passports. This document addresses the various issues initially presented in ATL-IT-QP-0078.

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Distribution List

- **atlas-trt-barrel mailing list**

History of Changes

Version.Revision	Date	Pages	Description
ATL-IT-QP-0078 v.1	23 May 2001		Original document by D.Froidevaux, A.Romaniouk, F.Dittus, covering both, TRT barrel and TRT end-cap.
Draft releases	27. Feb 2004		New document specific to TRT barrel, giving more detailed specifications and criteria (as applied in practice).
1.0	???		First version approved up to specifications for acceptance tests in building 154.
1.1	4-Mar-2004		Fixed typo on wire offest: in microns, not mm! Section 1.4.2 on Duke gain mapping shortened and edited Section 2.4: criteria for MGM: width > 7.9% Leakage currents are specified before capacitors insertion in section 2.3.

Table of Contents

1 Acceptance tests at assembly sites 4
1.1 Dimensional checks (envelopes) 4
1.2 Fluid-tightness tests 4
1.3 High-voltage tests 4
1.4 Gas-gain uniformity measurements 5
2 Acceptance tests in Building 154 6
2.1 Dimensional checks (envelopes) 7
2.2 Wire tension measurements 7
2.3 High voltage tests 7
2.4 Gas-gain uniformity measurements 8
2.5 Final fluid-tightness tests 9
3 Acceptance Tests in SR-1 9
3.1 Pre-Installation Module Tests 9
3.2 Installation - Phase I 10
3.3 Installation - Phase II 11
4 Acceptance Tests in UX-15 11
5 Module passports: 11
REFERENCES 12

1 Acceptance tests at assembly sites

The set of criteria presented here does not address quality control procedures and specifications occurring during the assembly process of barrel modules, which are meant to be an integral part of the assembly process itself and, as such, are documented in the assembly manuals. The criteria laid out in this paper refer to the measurements and tests performed on completed barrel modules before they are shipped to CERN. The only exception is in the case of the measurement of the leakage current between different high-voltage (HV) groups which are measured before stringing. The production sites are Duke University, Indiana University and Hampton University.

1.1 Dimensional checks (envelopes)

All critical dimensions are to be measured and compared to the envelope drawing specifications. Any non-conformities should be entered into the module passport. The minimum and maximum barrel module lengths are 1462.0 and 1464.0 mm, respectively. See the following drawings: ATLITB_0004, ATLITB1_0001, ATLITB2_0001 and ATLITB3_0038.

1.2 Fluid-tightness tests

Final fluid-tightness tests are carried out once pipe connections and and other seals are installed, as well as after module completion,

1.2.1 Active gas

Specifications: for the active gas, the target is to achieve a leak rate below 0.1 mbar/min/bar. But modules/wheels with leak rates up to a factor 10 times larger can be accepted. The tests are to be done with pure Argon at 20 mbar (0.3 psig) over-pressure except at Hampton University where 30 mbar is used for the system pressure. The test is conducted over a 16-hour period.

1.2.2 Cooling/ventilation gases

Specifications: the cooling/ventilation gas connections and seals have to achieve gas-leak rates below 1 mbar/min at 5 mbar (or so) over-pressure.

1.2.3 Liquid cooling

Specifications: for the cooling pipes and their connections, fluid-tightness is tested using an appropriate gas, and the target is to achieve a leak rate below 10^{-5} cm^3/min at an absolute pressure of 3 bar.

1.3 High-voltage tests

1.3.1 HV breakdowns between straws and shell

This test is not conducted at Duke University after module completion but is part of the test with active gas described in section 1.3.3. At Hampton, the test is done at 1700V in air whereas at Indiana, this test is performed at 2000 V, with wires floating and a CO_2 purge both in the shell and straws volume. In this test setup, the leakage current depends mostly on the moisture level in the radiator volume, which in turns depends on atmospheric conditions. Drying the radiator requires a long purge with CO_2. Since this was not compatible with the production schedule, the quantitative measurement is only done at CERN after HV conditioning, when the module radiator is completely dry. See section 2.3.4.

Specifications: with the shell grounded, ensure that there are no HV breakdowns.

1.3.2 HV breakdowns between HV groups (2.5 kV, before stringing):

This test is done in air at Duke University, active gas at Indiana University and with CO_2 purged in the radiator volume. It is performed after mechanical assembly but prior to stringing so it is not part of the tests performed by Hampton University. The circuits are tested by sequentially raising each HV trace and each corresponding group of straws to 2.5 kV while holding all the other traces and groups at ground. Each group is held at 2.5 kV for one minute.

Specifications: a group of straws is accepted if it draws less than 1-2 uA of current and shows no indication of breakdown with the current limit set to 80 uA. The exact current draw here depends on atmospheric conditions. Non-confirming groups are returned for rework.

1.3.3 HV checks in Ar/CO2 (wires at ground)

Each wire is test individually with 1700 V in air while the module is still on the stringing machine. The test with Ar/CO_2 is performed slightly differently at the three production sites:

Duke University: with air in radiator volume

- operate module for 2-3 days at 1600 V without trips

Hampton University and **Indiana University**: with CO_2 in radiator volume

- operate module for 24 hours at 1550 V without trips
- total leakage current less than 50 nA per module (this can only be measured in winter when the atmospheric humidity levels are low).

Reverse-voltage is applied for a few hours at a maximum of +1300 V to cure problematic wires. Hot wires that cannot be cured are identified and replaced.

1.3.4 Acceptance specifications for HV

- Less than 1% of dead channels
- Less than 4 HV groups with interconnections

1.4 Gas-gain uniformity measurements

All modules are gain mapped prior to leaving the um United States either at Duke University or at Hampton University. The gas mixture for these tests is Ar/CO_2. Tests by Kaioumov *et al.* using an ^{55}Fe source found that the gain in Ar/CO_2 70%/30% increased by about 5.5% for an offset of 300 um, and about 11% for an offset of 400 um. Straws with eccentricity above 400 um cannot be operated reliably. The signal wires for these straws have to either be replaced if the problem is due to a hung wire, or be removed if it is due to a bent straw. The repair work is done at CERN. Both the gain variation and the width of the peak in the pulse height spectrum are used to determine if the gain variations are due to a wire offset or some other cause. The following observations have been made:

- a wire offset is characterized by large variations in gain and width.
- contamination can be detected by the presence of one or a small number of points with low gain values and high widths.
- wire diameter variations correspond to high gain values but no variations in the width of the peak in the pulse height spectrum.

All wire segments (front and back) are reviewed at a Quality Circle meeting to make sure that the following two criteria are achieved:

1. For wires segments having gain variations above 8.0%, the width of the peak in the pulse height spectrum must be below 7.5%.
2. A wire segment will be declared conforming if the gain variation falls below 8.0% after removing one or a small number of points with low gain values. These low gain points are assumed to be caused by contamination which will be cleaned out by irradiation under normal operation.

The tests setups and definitions used at Hampton and Duke University are described separately here:

1.4.1 Hampton University gain variation measurements:

The gain is measured on the Module Test Station (MTS) using photons of 12 keV from bromine XRF, with the HV set to 1255V. A reference spectrum from ^{55}Fe is collected from another straw simultaneously and used to normalize the gain to reduce variations due to environmental changes.

The following parameters are used to describe the gain variation: for each measured point i along the straw, $g_n(i)$ is the gain normalized to a ^{55}Fe reference spectrum. It is scaled arbitrarily: $g_n(i) = 500\ x_{Br}(i)/x_{Fe}(j)$, where $x_{Br}(i)$ is the mean of the Gaussian fitted to the peak obtained from bromine XRF, and $x_{Fe}(j)$ is the mean of the Gaussian fitted to the ^{55}Fe reference spectrum. The (uncorrected) gain variation *G* is defined as $G = 100\%*(g_{n,max} - g_{n,min})/g_{n,min}$ for that wire segment. Here $g_{n,min}$ and $g_{n,max}$ are the minimum and maximum value of $g_n(i)$ for this wire segment The above criteria, expressed in term of *G*, become:

- *G* > 5% is likely to be due to a wire offset of 300 um
- *G* > 8% and width greater than 7.5% is sufficiently likely to be due to a wire offset of 400 um um to be removed or replaced.

1.4.2 Gain mapping at Duke University:

The Delta G =$(G_{max}-G_{min})/G_{min}$ is determined from the rescaled "corrected" mean values, where G_{max} is the maximum gain along half the straw length and G_{min} is the minimum gain along the same segment of the straw. The root mean squared (rms) of the widths from the gaussian fits of the raw data are determined for each straw. Straws with Delta G > 8% and rms>2 are flagged for further visual review. Wire segments with no data and those with regions of low gain are also flagged. Low gain straws are straw that have at least one *z* position with gain less than 40% of the average gain for the straw (the average gain is only determined from straws with gain between 400 and 650.

Specifications: 95% of straws must have an eccentricity below 300 um and 100% of straws with an eccentricity below 400 um.

2 Acceptance tests in Building 154

The results of the tension test, HV checks and gain mapping report from Hampton or Duke University will be used to identify wires that need to be replaced. A first leak check is also performed on the straw volume and the shell to identify leaky straws and leaky shells. All repairs for blocked cooling sleeves, blocked ASDBLR sockets, leaky straws etc will be performed before the module undergoes the final HV checks. After rework, the module will be tension and HV tested again before undergoing HV conditioning and gain mapping with the Module Gain Mapper. When all tests and repairs are completed, the module will be leak tested and certified for readiness before shipping it to the SR building for installation on the Barrel Support Structure.

2.1 Dimensional checks (envelopes)

All main envelope parameters are to be re-measured once the barrel modules arrive at CERN. The length is measured and checks are made for bulges, twists and blocked cooling sleeves.

Specifications:

- barrel modules length, R_{min}= 1462.0 mm, R_{max}=1464.0 straightness of supported module better than 100 mm.
- bulges in the shell must not exceed 0.8 mm
- twists of one tension plate with respect to the other shold not exceed 1.0 um
- and blocked cooling sleeves.

2.2 Wire tension measurements

Specifications: for all wires, the tension should be larger than 47 g (125 Hz) and less than 100 g (180 Hz).

All tension data collected at the production site, before gain mapping and at CERN will be compared to:

- find all wires with a tension below 47 g or above 100 g;
- find all wires where a change greater than 5g (8 Hz) has occured between two sites
- find all wires that have a front-back difference greater than 5g (8 Hz).

These wires will be replaced and re-tested.

2.3 High voltage tests

2.3.1 Check of all electrical connections

- check the electrical connection for each capacitor barrel pin by applying about 100 V on the module and measuring the voltage on each capacitor barrel. Note all anomalies in the acceptance passport.
- check the connection for the ground wire between the front and back tension plate. Repair if broken.
- check for broken traces on the HV Kapton connectors by applying a voltage at one end and reading it from the other end. Note all anomalies in the passport.
- Record in the acceptance passport all HV groups that are interconnected according to the production site passport.

2.3.2 HV checks (active gas: Ar/CO_2, CO_2 in radiator volume, wires grounded)

The module is prepared for HV checks by flushing dry CO_2 for several days in the radiator volume prior to testing.

Specifications:

- each wire must hold 1550 V (gain = 10.0 X 10^4) without trips for 3 days
- leakage current below 20 nA per module at 1550 V (without any capacitors)

For wires drawing excess current or modules having too many trips during HV checks, reverse-voltage is applied at a maximum of +1300 V to cure problematic wires. The duration depends on the current behavior and is usually of the order of 30-60 minutes. Wires that cannot be cured or wires that cause repeated trips are identified and replaced if found during the first HV checks. The module is retested under the same conditions after rework. Identified wires that cause trips at this point are removed.

2.3.3 HV conditioning (active gas: Ar/CO_2, CO_2 in radiator volume, wires grounded)

The HV conditioning will take place after all final tension tests and HV checks after rework.

Test conditions:

- apply 1480 V (gain = 5.0 X 10^4) for three weeks
- apply 1550 V (gain = 10.0 X 10^4) for one week
- leakage current below 20 nA per module at 1550 V (without any capacitors)

Specifications:

- each wire must hold 1480 V (gain = 5.0 X 10^4) without trips for the last week
- each wire must hold 1550 V (gain = 10.0 X 10^4) without trips for the last 3 days
- leakage current below 20 nA per module at 1550 V (without any capacitors)

Remove all non-conforming wires.

2.3.4 Leakage current at 2000 V in CO_2

After one month of HV conditioning performed as described above, CO_2 will be circulated in the straws overnight in addition to the radiator volume. This test is performed before capacitor insertion.

- measure the leakage current after 15 minutes at 2000 V with all wires and the shell grounded.
- measure the leakage current through the shell with all wires floating after maintening the module at 2000 V for 15 minutes.

Specifications: The leakage current should be below 20 nA per module for both tests. Wires shorting out should be identified and removed. Any failure and anomalies should be noted in the acceptance passport. The module shell should be able to hold 2000V with shell grounded for 15 minutes.

2.4 Gas-gain uniformity measurements

Modules are gain mapped at CERN after rework based on gain mapping measurements in the U.S., first and results from HV checks and tension measurements at CERN. The criteria to accept wires are: gain variation less than 8% and peak width less than 7.9%. These criteria are similar to those described in Section 1.4; the difference in the width cut reflects the difference in calibration between the MTS and the MGM. New wires and wires that did not receive a valid measurement during gain mapping in the U.S. will be particularly scrutinized. Although the mapping device at CERN (the MGM) is not identical to the MTS at Hampton, the criteria are currently the same. Non-conforming wires detected at this point (i.e. with gain variation $G > 8\%$ and peak width at maximum gain $S > 7.9\%$) will be reviewed and possibly removed.

Specifications: 95% of straws should have $G < 5\%$ and $S < 7.9\%$ and 100% of straws should have $G < 8\%$ and $S < 7.9\%$.

2.5 Final fluid-tightness tests

2.5.1 Active gas

Specifications: for the active gas, the target is to achieve a leak rate below 0.1 mbar/min/bar. But modules/wheels with leak rates up to a factor 10 times larger can be accepted. The test is done with Argon at 20 mbar (0.3 psig) over-pressure. The test is conducted over a 12 to 16-hour period. This test is done after all non-conforming wires found during the HV conditioning and with the Module Gagin Mapper have been removed and sealed.

2.5.2 Ventilation gas

Specifications: the cooling/ventilation gas connections and seals have to achieve gas leak rates below 1 mbar/min at 5 mbar (or so) over-pressure. The test is done by pressurizing the module with about 10 cm of water (10 mbar). The decay time should be greater than 5 minutes.

3 Acceptance Tests in SR-1.

After modules acceptance testing in building 154, modules are transported to building SR-1. There the modules are installed in the Barrel Support Structure (BSS). Prior to installation, the modules have their capacitors installed and a number of associated pre-instillation module tests are performed. The modules are then ready for installation into the Barrel Support Structure.

The installation process is performed in two phases. The first phase consists of installing modules, protection boards, active boards/cooling plate sets, and service hookups. A variety of acceptance tests are performed during this process. The second phase consists of installing the service manifolds and testing sectors corresponding to each PPB1 sector. A number of acceptance tests are performed during this process. Joint SCT and TRT Barrel acceptance tests may also be performed in phase II

3.1 Pre-Installation Module Tests

Prior to installation in the BSS, the modules have the capacitors installed and tested. All capacitors are tested at Duke University prior to shipment to CERN. All modules are tested for leak tightness in Bld 154 prior to shipment to the SR-1 building. Capacitors are inserted into the modules in the SR-1 building, tested, sealed, and tested a final time. The purpose of this testing is to verify that: the capacitor encapsulation process had no negative side-effects; the capacitors and associated pins were not damaged during installation; the capacitor pins make good contact; and the capacitors have not failed.

3.1.1 Capacitance Test

After capacitor insertion, the capacitance between HV group (anode) and ground is measured with a DVM w/capacitance meter.

Specification: The capacitors in the group are accepted if the measured capacitance is > 10 pf . (Note: University of Pennsylvania is investigating the appropriate value which may be different than the above value)

3.1.2 HV Test Prior to Sealing

Before the capacitors are sealed in the capacitor barrels, a High Voltage Test is conducted. This test is performed in air, with the voltage set at 1500 volts for 15 minutes. The wires are left floating.

Specification: The capacitors are accepted if there are no trips in 15 minutes and the total module current is < 50 nA.

3.1.3 Sealing Test

The capacitors are sealed in the capacitor barrels to ensure leak tightness should the capacitor barrel fail. Capacitors are sealed with approved glue and the seals are visually inspected.

Specification: The capacitor seals are accepted if there is no evidence of gaps, pin holes, or other defects in the seals.

3.1.4 HV Test after Sealing

The capacitors are tested after sealing to ensure that the capacitors were not damaged during sealing. This test is conducted in air with the voltage set at 1500 volts for 15 minutes. The wires are grounded for this test.

Specification: The sealed capacitors are accepted if there are no trips for 15 minutes and the total module current is < 50 nA.

This completes all module acceptance testing prior to insertion into the BSS

3.2 Installation - Phase I

Phase I testing is intended to verify that individual modules are functioning properly. The specific tests are as follows

1. Verify Ventilation Gas Leak Tightness
2. Verify Ventilation Flows and Pressure Drops
3. Verify Protection Board insertion
4. Verify High Voltage Connectivity and Standoff
5. Verify Low Voltage Connectivity and Current
6. Verify Cooling Plate Leak Tightness
7. Verify Cooling Plate Flows and Pressure Drop
8. Verify Active Gas Leak Tightness
9. Verify Active Gas Flows and Pressure Drop
10. Verify Active Board Functioning

3.3 Installation - Phase II

Phase II testing is intended to verify services performance and multi-module performance by sector. The following tests are performed for each sector.

1. Verify Ventilation Gas Leak Tightness
2. Verify Ventilation Flows and Pressure Drops
3. Verify Cooling Leak Tightness
4. Verify Cooling Flows and Pressure Drops
5. Verify Active Gas Leak Tightness
6. Verify Active Gas Flows and Pressure Drops
7. Verify High Voltage Connectivity and Standoff
8. Verify Low Voltage Connectivity and Current
9. Verify Active Board Performance
10. Verify Shielding and Grounding
11. Verify Barrel and SCT Joint Performance?

4 Acceptance Tests in UX-15

Acceptance tests in UX-15 are intended to verify services performance and full barrel performance when the barrel is installed.

1. Verify Ventilation Gas Leak Tightness
2. Verify Ventilation Gas Flows and Pressure Drops
3. Verify Cooling Leak Tightness
4. Verify Cooling Flows and Pressure Drops
5. Verify Active Gas Leak Tightness
6. Verify Active Gas Flows and Pressure Drops
7. Verify High Voltage Connectivity and Standoff
8. Verify Low Voltage Connectivity and Current
9. Verify Active Board Performance
10. Verify Shielding and Grounding

5 Module passports:

There will be three passports for each module:

- a production passport from the production site (obtained from the production databases for modules completed at Indiana or Hampton University, and from http://atlas.phy.duke.edu/production/summary/ for modules completed at Duke University.)
- a gain mapping passport from the gain mapping site (samples passport from Hampton University can be found in http://atlas-trt-barrel.web.cern.ch/atlas-trt-barrel/HU-Passports.htm and from Duke University in http://atlas.phy.duke.edu/production/xray/)
- the final acceptance passport (see http://trt-wts.web.cern.ch/trt-wts/passp/blogin.html with appropriate password).

The production passport

This passport gives a summary of dimensions, weight, anomalies, dead channels (plugged straws and straws with wires removed), active gas leak rate, HV test leakage current without capacitors, shorts between HV groups, tension test results etc. They come in different formats, but all passports contain the same information. All information is kept in the production databases and will ensure long-term traceability.

The gain mapping passport

This passport provides a summary of all gain variations and widths measured for each wire segment (front and back). It is based on the gain mapping database and all basic information such as spectra at various points for each segment will be available from the database using some special tools developped for the gain mapping data analysis. In particular, this passport contains:

- a count of all wire segments with gain variations exceeding 5%
- a count of all wire segments with gain variations exceeding 8% and width above 7.5%
- spectra and gain variations for all wires with gain variations exceeding 8% and width above 7.5%
- a full list of gain variations and widths for all wire segments

The acceptance passport

This passport contains the results of all acceptance tests performed at CERN, anomalies and final repairs done at CERN as well as selected information from the production sites on which rework and repair decisions are based:

- a summary of all dead channels
- summary of all remaining anomalies either reported by the production sites and not fixed at CERN, or discovered at CERN and found impossible to repair
- report on dimensions checks
- comparative study of tension data between the production site, gain mapping site and CERN
- summary of gain mapping results in the United States and at CERN showing a 2-D map of the gain variations for all wire segments and a summary table of the status of all wires having a gain variation of more than 8%.
- summary of all repairs, including a list of replaced wires and removed wires
- complete report on HV tests, HV conditioning, leakage currents without capacitors and anomalies noted during the tests
- leak rate for the active gas volume.

The acceptance passports can be seen from http://trt-wts.web.cern.ch/trt-wts/passp/blogin.html. The information resides in a CERN-based Oracle database maintained by the PNPI group, in parallel with the similar end-cap wheels passport and database. The web interface allows users to enter or review information from anywhere.

REFERENCES

1