AUT QUANTIFICATION GUIDANCE

Guidance for Quantification of Automated Ultrasonic Testing Systems for Examination of Pipeline Girth Welds

Issued by: EWI

Revision: 5

Revision Date: February 18, 2011

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1.0 Scope

This document describes the process for quantifying automated ultrasonic testing (AUT) capabilities for examination of girth welds on new construction cross country pipelines. The process in this document is intended to provide guidance for quantifying the three major components that comprise an AUT system used for girth weld testing. These components are:

1. AUT equipment
2. AUT procedures
3. AUT operators.

The purpose of the quantification process is to provide quantifiable data of how well a proposed AUT solution will perform to meet weld examination objectives stated by the applicable code, standard, specification, or other governing document. Output from the quantification process will consist of numerical results of flaw detection and sizing performance for any or all of the three AUT components listed above.

Data for the quantification process described in this document is obtained by one, or a combination of, the following methods:

- Documentation from previous quantification/qualification programs, modeling and inspection simulations, or other engineering calculations.
- Statistical performance evaluation to determine probability of detection (POD) and sizing accuracy involving a statistically significant number of implanted or natural flaws.

It is recommended that the quantification Administrator establish detailed written procedures or methodologies in accordance with this guidance document for conducting the quantification process.

The extent of the quantification process will largely be determined by the applicable codes, standards, or other governing documents related to construction and quality of the pipeline. The quantification process may be accomplished as part of an AUT qualification.[1-3] program or as a separate activity. While qualification focuses primarily on whether an AUT system meets or does not meet requirements, quantification provides numerical data as to how well an AUT system performs. Results from the quantification process provide numerical data for the AUT system that may then be used in establishing the final allowable flaw size for an AUT examination.

2.0 Acronyms and Definitions

Following are definitions of acronyms and terms used within the scope of this document:

- Administrator – Company or organization conducting AUT quantification as described in this document. This can be the Pipeline Operator or third-party Designate who has the technical knowledge and experience required to perform the Quantification process. The administrator's AUT specialists should specifically have a good understanding of equipment and procedures used for AUT of pipeline girth welds and a demonstrated knowledge of interpretation of AUT girth weld results. It is recommended that the AUT specialist be a certified UT Level III per SNT-TC-1A or similar. Likewise, it is recommended that the Administrator use personnel trained in the statistical methods used for AUT quantification. Personnel should be able to demonstrate an understanding of the statistical processes and the limitations of each.

- AUT – Automated ultrasonic testing.

- AUT Equipment – The hardware and software by which the AUT examination is implemented. Equipment includes, but is not limited to: cables, probes, pulser-receivers, amplifiers, scanner, and data acquisition and data processing software.

- AUT Operator – Examiner using ultrasonic equipment to perform AUT.

- AUT Qualification – Successful documentation of an AUT system's ability to demonstrate established qualification objectives in compliance with the requirements of a specification, standard, code or other governing documents.

- AUT Quantification – A systematic quantitative assessment of an AUT system's ability to detect and size flaws. Quantification of the AUT system may be a separate activity or conducted as part of the AUT Qualification where required.

- AUT (Examination) System – AUT personnel, procedures, and equipment used to evaluate the flaw characteristics of pipeline girth welds.

- AUT Vendor – Company or organization providing AUT services.

- Blind Trials – Practical AUT trials in which the AUT operators performing the examination do not have specific and detailed knowledge of the numbers, sizes, orientations, and positions of flaws in the specimens. This is normally part of a formal quantification procedure supervised by the Administrator.

- Contracting Party – The party contracting AUT services. The contracting party is responsible for providing weld examination requirements from applicable codes, standards, specifications, and other governing documents to the AUT Vendor and to the Administrator. The Contracting Party may be the Pipeline Operator or a third party.

- Detectability – Capability of AUT equipment, personnel and procedure to detect flaws in a girth weld.

- ECA – Engineering-critical assessment. Engineering calculations used to determine critical flaw sizes based on loading conditions and testing inaccuracies.

- Flaw Axial Position – Position with respect to the weld center line (upstream or downstream).

- Flaw Circumferential Position – Distance between the scan-starting-reference point and the flaw start and flaw end points. The positions are also known as flaw start-stop positions. The circumferential position where the flaw height reaches maximum is required for data processing purposes as well.

- Flaw Depth – Distance from the pipe outside diameter (OD) surface (excluding cap reinforcement) to the bottom of the flaw.

- Flaw Height – Extent of the flaw in the through wall thickness (along the pipe radius).

- Flaw Length – Extent of the flaw in the circumferential direction.

- GTAW – Gas tungsten arc welding.

- AUT Procedure – A document that describes how the specific AUT examination will be performed and how essential variables affecting the AUT performance will be monitored and controlled.

- Open Trials – Practical AUT trials in which the AUT operators performing the examination have specific knowledge of the flaws in the specimens. It is normally part of a formal quantification procedure supervised by the Administrator.

- Pipeline Operator – The owner of the pipeline.

- POD – Probability of detection. For the purposes of this document, POD(a) is the probability of detection of flaws with size **a**.

- Quantification File – An assembly of information relevant to the definition and execution of the AUT quantification. It includes information on flaws, specimen and weld geometries, technical justification (TJ), AUT procedure, and results from the AUT quantification.

- Sizing Error – Differences between AUT flaw measurements and reference measurements. Reference measurements are typically obtained through metallographic cross sections of the flaws.

- Technical Justification (TJ) – Documentation providing evidence that the AUT equipment, procedure and personnel (operators) can meet stated objectives. The documentation shall contain numerical data to quantify AUT performance.

- TOFD – Time-of-flight diffraction ultrasonic technique.

- Weld Sector – A sector from the girth weld circumference with or without flaws used for assessment of AUT capabilities.

3.0 The Quantification Process

The quantification process is a systematic assessment of the AUT equipment, procedure and/or AUT operators to determine flaw detection and sizing performance.

The AUT quantification process is accomplished through two major activities – Technical Justification (TJ) and, if required, practical trials. In general, the AUT equipment and procedures can be quantified through TJ and/or by open trials, while AUT operators will be quantified through TJ or blind trials. While AUT equipment and procedures can be quantified using open trials, industry typically uses blind trials to quantify the entire AUT system (equipment, procedures, and operators).

Results of AUT quantification/qualification will provide a pipeline contractor or pipeline operator with information about the ability of AUT equipment, procedure, or operator to meet weld examination objectives. The information will typically contain POD and sizing accuracy statistics for some or all of the three quantification components previously mentioned. In some cases, quantification may be accomplished by review of TJ documents from previous qualification or quantification trials.

The Contracting Party, Administrator, and AUT vendor are all involved to determine the scope and performance level of the quantification process needed to meet applicable requirements. It is important to identify the AUT performance level early in the construction planning process so that adequate time and resources can be allotted. As an example, for high performance levels using a probabilistic approach, several weld specimens will need to be designed, fabricated, tested by AUT vendors, and then destructively sectioned and measured at each flaw location. This process can take several months and requires good coordination between the different entities involved. Appendix A contains a Gantt chart showing approximate times for each task. A list of the various parties and their typical responsibilities are shown below:

a) Contracting Party

- Provides information regarding the AUT equipment, procedure and personnel that require quantification
- Initiates the AUT quantification process and works with the Administrator to coordinate logistics for accomplishing the process
- Acquires TJ documentation and provides it to the Administrator
- Responsible for flowing down AUT weld examination requirements from applicable codes, standards, specifications, and other governing documents to the AUT vendor and to the Administrator.

b) Administrator

- Conducts the quantification process in accordance with written procedures using qualified personnel. The Administrator's quantification process should be auditable.
- Assesses TJ documentation
- Designs, fabricates, and fingerprints the quantification specimens as needed
- Coordinates any practical trials
- Assesses the quantification results
- Prepares the quantification file and issues the quantification report

- Exercises confidentiality with regard to items considered proprietary or business sensitive
- Maintains quantification files.

c) AUT Vendor

- Prepares the AUT procedure and TJ documents
- Participates in quantification study
- Assists the Administrator in maintaining the quantification file
- Performs AUT of girth welds

4.0 Technical Justification (TJ)

Since the quantification process can be time consuming and costly, TJ offers a means to reduce the number of practical trials required; and in some cases TJ may be sufficient to eliminate practical trials. TJ should be required when there are any changes in AUT essential variables from a previous quantification that are outside the approved range of variability.[4] Acceptable variability of essential variables will depend on the specific application and will need to be determined either experimentally, through modeling and simulation, or by other means agreed upon by the Contracting Party and Administrator. A typical list of essential variables is provided in Table 1.

The purpose of the TJ is:

- Provide documented numerical data of the capability for an AUT system or equipment to perform to the required level.

- Complement practical trial results and provide a sound technical basis for reducing the number of practical trials.

TJ would typically be used for extending current quantification results to accommodate a slightly different weld or pipe geometry, changes in AUT equipment hardware or software, a revised procedure, and for quantification of AUT operators. TJ comprises a mixture of previous qualifications/quantifications, experimental evidence and theoretical assessments. The TJ may contain the following:

- Introduction
- AUT equipment documentation
- AUT procedure
- List of AUT essential variables and quality verification checks
- Previous qualification/quantification results and the statistical calculation method used
- Predictions by modeling and inspection simulations
- Experimental documentation
- Additional documentation as needed.

The Contracting Party, Administrator, and AUT vendor should decide on the scope and contents of the TJ, as well as, the level of complexity and balance between the TJ and any practical trials. The Administrator should review the documentation to determine if a valid quantification can be made based on the TJ. After completing the review, a report should be prepared by the Administrator that contains conclusions and recommendations from the TJ assessment. This

report should be issued to the Contracting Party and the AUT Vendor. If practical trials are needed, the Administrator should coordinate with the Contracting Party and AUT Vendor to conduct the practical trials.

It is recommended that the Administrator have a written procedure detailing the process for compiling and assessing the TJ and for reviewing the AUT procedure. Reference 5 is an example of this document.

5.0 Design and Fabrication of Practical Trial Specimens

Typically, the Administrator will be responsible for designing and building specimens for practical trials. The number, types, sizes, and locations of flaws or reflector targets will depend on the performance level requirements and should be approved in advance by the Contracting Party. Details regarding specimens to be used for blind trials should be kept confidential by the Administrator.

Specimen fabrication: In general, specimens shall be fabricated from material that closely matches the pipeline material to be used for construction. Specifically, it is important that pipe diameter, thickness, and metallurgical and acoustical properties be similar. In addition, welds shall be of the same groove geometry and tolerances as the welds for which the quantification applies. It is recommended that the welding process be the same as actual production welds except localized GTAW is permitted for flaw fabrication. When using GTAW for flaw implantation, it should be noted that acoustical properties could be different than those for natural weld flaws caused by changes in welding parameters.

The weld circumference should be divided into equal sectors of approximately 20 to 50 mm in circumferential length and numbered consecutively in the scanning direction. Sector numbers and boundary lines may be marked on the pipe using a vibratory engraver provided they do not interfere with the ultrasonic test.

Specimens should contain weld flaws created by implanting or by varying welding parameters. A typical ratio of weld sectors without flaws to those with flaws might be in the range from 1:1 to 3:1. Other ratios may be used to provide better flaw separation or sufficiently long areas for false calls and noise estimates. To closely simulate actual flaws it is recommended that flaws be produced by varying the welding parameters; however, implanted flaws are generally more precise with respect to type, size, and location. Flaws should vary in location, length, and height. Only one flaw should be located at any circumferential location and flaws should be separated by at least 12 mm from the end of one flaw to the beginning of the next. It is recommended that flaws be at least 12 mm in length unless the acceptance criterion dictates that shorter flaws be detected. Both volumetric and planar flaws may be used, but it is recommended that only planar flaws be used for determination of POD and sizing accuracy. Volumetric flaws should only be used to verify detection. When samples contain multiple flaws in close proximity, such as when evaluating flaw interaction rules, these flaws should be excluded from the flaw population used for POD and sizing calculations.

Number of flaws: The number of flaws for practical trial specimens will depend on the performance level required for the AUT application. It is common to calculate POD based on a 90% probability of detection with a 95% confidence level. This criterion will generally require at least 60 flaws; however, it is recommended that a minimum of 120 flaws be used. This number may be reduced if inspection modeling and simulation is used to narrow the range of flaw sizes required to determine POD and sizing capabilities.

Flaws should be evenly distributed throughout the weld thickness. To achieve good flaw distribution, it is recommended that the weld thickness be divided into layers according to changes in the weld bevel design. This will generally require at least three thickness layers: cap, root, and fill. Other layers may be desired in locations where the bevel angle changes significantly, such as the hot pass zone. It is recommended that each thickness layer contain at least 29 flaws of varying sizes.

Fingerprinting: Once specimens are fabricated, it is recommended that they be inspected using TOFD and a high gain phased-array sector scan technique incorporating a mechanical raster scan. This will provide good reference data for verifying that intentional flaws are correctly implanted and to identify any unintentional flaws or other weld anomalies. Previous fingerprinting using these techniques has demonstrated an average sizing error of only about 0.3 mm, when compared to metallographic cross-sectioning.[6]. Other NDE methods and techniques such as radiography, magnetic particle, penetrant, visual, and eddy current may also be used as applicable. After AUT scans are completed, a ring containing the weld may be cut from the specimens and scanned using immersion UT C-Scan. Scanning should be done from both the upstream (US) and downstream (DS) faces of the ring. The cut surfaces should be machined as needed to provide a good surface for UT inspection. When using immersion UT for fingerprinting, reflectors may be machined into the rings to aid in establishing scan sensitivity and distance calibration.

It is recommended that the Administrator have a written procedure describing design and fabrication of practical trial specimens. Reference 7 is an example of this document.

6.0 Practical Trials

When TJ alone does not meet the performance level requirements, practical trials are required. The scope of practical trials is determined by the AUT performance level needed, as well as, the AUT components being assessed. When determining only the performance of AUT equipment and procedures, open trials may be used if approved by the Contracting Party. If the performance of AUT operators is to be determined, either separately or in conjunction with AUT equipment or procedures, blind trials shall be used.

In all cases, AUT results shall be compared to flaw dimensions that are measured using a method having a greater accuracy. This measurement method is known as the "reference". The reference method may be other NDE techniques having better detection capabilities and higher accuracy than the AUT technique used for the trials, or it may be a destructive method such as metallographic cross-sectioning.

Scanning: The Administrator is responsible for coordinating and monitoring the practical trials. AUT vendors should inspect the welds using the test procedure that will be used for actual weld examination during pipeline construction and that has been previously approved by the Contracting Party. Scan start positions and scan direction should be in accordance with that stipulated by the Administrator.

Each specimen should be scanned in the same general angular position as is expected during construction (vertical, horizontal, etc.). If multiple weld orientations may be encountered, the Contracting Party can require that verification scans be performed to simulate these various orientations. These verification scans should be performed on a single specimen selected by

the Administrator or Contracting Party. The selected specimen should contain readily detectable flaws in each quadrant of the weld circumference.

The Contracting Party may also require additional scans to determine effects of variables such as temperature, band offset, and reversed scanning direction. Prior to beginning the practical trials, the number of additional scans and extent of scanning should be agreed upon between the Contracting Party, Administrator, and AUT vendor.

AUT Data Reporting: AUT vendors should interpret the scan data in accordance with the approved AUT procedure. Electronic copies of scan files (including calibration files) and data viewing software should be provided to the Administrator. In addition, reporting of data should be submitted to the Administrator in spreadsheet format as shown in the sample in Table 2. A high-resolution electronic image of the AUT output screen for each weld should also be provided to the Administrator. It is recommended that all test results and electronic files be provided to the Administrator within 3 business days after completion of the practical trials.

7.0 Destructive Verification

It is recommended that destructive verification (metallographic cross-sections) be used to verify flaw depth, height, and length (if required). Relying on flaw dimensions from fabrication drawings alone is likely to result in relatively large errors in statistical results. Using metallographic cross-sectioning, previous work.[6] has shown that average flaw heights were typically 1.4 mm greater than what was specified in fabrication drawings. The same study proved that flaw depth averaged 0.7 mm deeper than specified. While it is recommended that destructive verification be used as the reference measurement method for flaw depth and height, flaw length can usually be sufficiently determined with the NDE fingerprinting techniques previously discussed. The accuracy of NDE technique(s) selected for length measurements shall be validated by comparison to length measurements obtained by destructive methods.

When destructive verification is used as the means for obtaining reference measurements, locations for cross-sectioning should be selected based on the circumferential location of maximum flaw height for ECA applications, or maximum signal amplitude for workmanship criteria. Locations for cross-sectioning should be laid out using either a flexible tape scale that can completely wrap around the circumference, or by use of an AUT scanner that has a demonstrated accuracy of at least ±3 mm for the entire pipe circumference.

It is recommended that each flaw be cross-sectioned at the maximum location and that 2 to 3 macros be taken on each side of the maximum location at intervals of approximately 3 mm or less. When flaw length is part of the sizing accuracy determination, or the qualification is based on workmanship criteria, additional cross-sections should be made near the ends of each flaw to determine flaw length. Each macro should be identified with the weld number, the circumferential weld location (rounded to the nearest 1.0 mm) and should clearly indicate the US side of the weld. Macro surfaces should be ground and then polished to a final surface finish of 3 micron or finer. The surface should then by lightly etched using an etchant appropriate for the material.

Photographs should be taken of the polished macro surface using magnifications of 5 to 10×. Prior to taking photographs, it is recommended that the macros be viewed at magnifications up to 100× to accurately determine the full extent of the flaws. Each macro photograph should contain the following:

- Weld number
- Circumferential location
- Measurements showing the depth and height of any flaws (intentional or unintentional) having a through wall height of 0.3 mm or greater and a length of at least 6 mm
- Annotation identifying the US side of the weld
- A linear reference scale
- Depth and height measurements can be rounded to the nearest 0.1 mm.

It is recommended that the Administrator have a written procedure detailing the practical trial process and for performing practical destructive validation. Reference 8 is an example of this document.

8.0 Statistical Analysis

The Administrator should arrange destructive test results and results from the AUT vendor(s) into spreadsheet format to facilitate statistical calculations. Unintentional flaws smaller than 0.5 mm in height should be disregarded if they do not appear on at least two consecutive macros; or if it can be determined that the flaw length is less than 6 mm.

After compiling the AUT measurements and reference data into spreadsheet format, statistical analysis can be performed to quantify the AUT system or component. Two statistical methods are commonly used for POD calculations; binary regression and binomial distribution. Software packages are available that can make either calculation relatively simple, but it is recommended that the binary regression approach described in MIL-HDBK-1823[9] be used. Other recognized industry methods [e.g., Nordtest[10], PODv3] may also be used with concurrence of the Contracting Party. Regardless of the calculation method, it is important that all statistical comparisons be performed using the same calculation method and that the method be documented in the quantification file. The compiled raw data should be preserved to allow additional calculations in the future, or to allow comparisons to other calculation methods.

False Calls: During practical trials, false calls will generally be caused by factors such as material grain structure, geometry echoes, or mode conversion. Since flaw sizing accuracy is part of the quantification process any indication that can be verified as a weld flaw should not be counted as a false call. Determination of false calls should be done using destructive verification or by using fingerprinting results.

It is recommended that false calls be quantified based on the total number of weld sectors (refer to Section 5) scanned. A percentage of false calls should be calculated by dividing the total number of false calls by the total number of scanned weld sectors. The false call rate can also be calculated for a certain length of girth weld.

Outliers: Outliers in the data should be individually examined to determine the cause. It is recommended that outlier data points only be removed from the data set when it can be verified that the data point is invalid. Even when a data point is removed from the calculations, it should still be included in the tabulated data for reference purposes. All data points removed from the data set should be documented in the quantification report along with the reason for removal. There are several reasons why a data point could be considered invalid, including, but not limited to:

- Interaction of flaws in close proximity to each other
- Flaws outside the weld and heat-affected zone
- Pipe wall thickness changes outside allowable limits
- Flaw type not applicable or typical to actual welding process
- Statistically insignificant number of flaws causing essentially normal data to become not normally distributed at typical levels of statistical significance (e.g., 5 or 10%).

It is recommended that the Administrator have a written procedure detailing the statistical analysis process. Reference 11 is an example of this document.

9.0 Quantification Report

Upon completion of the quantification process, the Administrator should provide a report to the Contracting Party and AUT Vendor. As a minimum, the report should contain the following:

- Purpose and scope of the quantification.
- Results and comments from the TJ review and AUT procedure review.
- Description of the AUT equipment and procedure.
- Summary of the specimen designs used for practical trials.
- Details of how the AUT scanning was conducted.
- Description of the destructive validation process or other reference measurement techniques.
- Statistical results and a description of the calculation method used.
- For each AUT vendor tested, statistical results should include as a minimum, “a” 90/95 POD curve(s) for the dimension of interest (usually flaw height), 95% limit against undersizing, average sizing error, standard deviation of sizing error, and percentage of false calls. Although not required, it is recommended that the results be further reported for different depths within the weld; for example: cap, fill, hot pass, and root.
- It is also recommended that the report contain a plot of AUT predicted flaw dimension(s) compared to reference measurements and a plot showing AUT measurement errors for each flaw.
- Conclusions and recommendations, including whether the quantification results meet stated criteria provided by the Contracting Party and a list of essential variables and acceptable deviations.

10.0 Content and Maintenance of Quantification File

Throughout the quantification process a quantification file should be compiled and maintained by the Administrator. The file should contain the following items as applicable:

- Introduction
    - Purpose and scope of the quantification file
    - Description of layout of the quantification file
- Technical justification[5]
- AUT procedure
- Report of initial assessment of TJ and AUT procedure[5]
- Details of the quantification specimens, if required[7]

- Results from the open and blind trials and destructive validation if performed.[8] Results should include all AUT and destructive measurements used for statistical calculations of POD and sizing accuracy.
- Copy of the Quantification Report

11.0 Standardization of the Quantification Process

It is recommended that the Administrator develop standardized written procedures for performing the quantification process. Upon request, these procedures should be made available for review by the Contracting Party and AUT Vendors participating in the quantification process.

12.0 References

1. API 1104, Welding of Pipelines and Related Facilities, American Petroleum Institute (API), 20th Edition, October 2005.

2. ASTM E 1961, Standard Practice for Mechanized Ultrasonic Examination of Girth Welds Using Zonal Discrimination with Focused Search Units, Section 3 – Metals Test Methods and Analytical Procedures, Vol. 03.03 Nondestructive Testing, Annual Book of ASTM Standards

3. DNV Offshore Standard DNV-OS-F101; Submarine Pipeline Systems, October 2007, Amended October 2008.

4. European Methodology for Qualification of Non-destructive Testing, Issue 3, European Network for Inspection Qualification (ENIQ) Report No. 31, EUR EN 22906, published by the European Commission, Brussels-Luxembourg, August 2007.

5. Methodology for Contents and Review of Technical Justification (TJ), Edison Welding Institute (EWI).

6. EWI Project Report 50454GTH; “Advanced Technologies and Methodology for Automated Ultrasonic Testing Systems Quantification”.

7. Methodology for Design, Fabrication, and Fingerprinting of Quantification Welds, Edison Welding Institute (EWI).

8. Methodology for Practical Trials and Destructive Validation, Edison Welding Institute (EWI).

9. MIL-HDBK-1823A (2009), Nondestructive Evaluation System Reliability Assessment, Department of Defense Handbook.

10. NORDTEST Report, NT Techn Report 394, Guidelines for NDE Reliability Determination and Description, Approved 1998-04.

11. Methodology for Data Analysis, Edison Welding Institute (EWI).

Table 1. AUT Essential Variables

Welding method
Groove geometry
Nominal pipe wall thickness
Material
Wedge design
Probe design
Reference reflector type or size
Probe offset from weld centerline
Focal laws
Number or size of AUT zones
Working temperatures
System software changes affecting data acquisition or sizing algorithms
Detection thresholds

Table 2. Sample Table for Reporting AUT Practical Trial Results

Date:
Project:
Weld No.
Pipe Thickness:
Pipe Diameter:
Material:
Groove Geometry:

AUT Equipment:
AUT Procedure:
AUT Company:
AUT Operator:
Location of Inspection:

Sector No.	Flaw Type	Detection Channels	Axial Position	Circumferential Position		Length	Depth	Height	Maximum Amplitude (% FSH)	Comments
				Start	Stop					
S1										
S2	LOSWF	F2U, F3U	US	52	72	20	8.2	3.8	94	
S3										
S4										

Appendix A

Quantification Tasks and Approximate Timeline

Task	Approximate Duration (weeks)																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Contracting Party provide AUT examination requirements to AUT Vendor & Administrator																											
AUT Vendor provides relevant TJ documents & AUT procedure																											
Administrator review of TJ documentation & AUT procedure																											
Administrator & Contracting Party determine extent of quantification trials																											
IF QUANTIFICATION TRIALS ARE NEEDED																											
Administrator designs samples & coordinates fabrication																											
AUT Vendor fabricates calibration standards																											
Administrator fingerprints quantification samples																											
Administrator conducts quantification trials																											
Administrator performs destructive verification																											
Administrator performs statistical analysis																											
Adminsitrator reports results & issues certificate of compliance																											