FOREWORD

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— Service Specifications. Procedural requirements.
— Standards. Technical requirements.

The Standards and Recommended Practices are offered within the following areas:
A) Qualification, Quality and Safety Methodology
B) Materials Technology
C) Structures
D) Systems
E) Special Facilities
F) Pipelines and Risers
G) Asset Operation
H) Marine Operations
J) Cleaner Energy
O) Subsea Systems
Motives

This new document provides a uniform guideline for the general qualification of Automated Ultrasonic Testing (AUT) systems, ensuring that the qualification and project specific validation of any AUT system is according to the requirements of OS-F101 Appendix E and is consistently performed to comply with the specific requirements of the referenced code.

In principle, the guideline can be utilised for all materials but special care shall be taken for applications where inconsistent wave propagation or other wave physics are affected by structural properties.
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1. Introduction

1.1 Scope

The Scope of this document is to provide a uniform guideline for the general qualification of Automated Ultrasonic Testing (AUT) systems according to the requirements for qualification of such systems given in Appendix E of DNV Offshore Standard OS-F101, Submarine Pipeline Systems 2007. This qualification activity will document the specific AUT system performance in terms of inherent functionality related to non changeable hardware, software and calibration philosophy. Qualification activity following this guideline will also document the AUT system performance in terms of PoD and sizing capabilities relevant for applications where the essential variables remains within the specified tolerance as given in OS-F101 Appendix E Section H400 and Section 2.4 in this document. The intention with this general qualification is to provide a repeatable and auditable process for AUT system qualifications allowing project specific validations where the scope for the project specific validation can be designed to verify compliance with the general AUT system performance as documented in the general qualification. The extent of this validation will depend on the identified deviations from essential variables referenced in OS-F101 Appendix E section H400 and sect 2.4 in this document as well as any pre requisites referenced in the general qualification document. A recommended scope for a project specific validation is included in this RP.

This document will describe in details the specific system requirements, input requirement, qualification process and data analyses process. The scope includes qualification of any AUT system to document reliability, repeatability and accuracy for detection and sizing of defects in pipeline girth welds. In principle, the guideline can be utilised for all materials but special care shall be taken for applications where inconsistent wave propagation or other wave physics are affected by structural properties such as anisotropic materials. In such applications, a specific assessment shall be made to determine the adequacy of the implementation of this guideline.

1.2 Objective

The objective of this document is to ensure that the qualification and project specific validation of any AUT system is according to the requirements of OS-F101 Appendix E and is consistently performed to comply with the specific requirements of the referenced code.

1.3 References

/1/DNV Offshore Standard OS-F101, Submarine Pipeline Systems, 2007

1.4 Acronyms and Definitions

1.4.1 Acronyms

- AUT: Automated Ultrasonic Testing
- CW: Clockwise
- CCW: Counter-clockwise
- DNV: Det Norske Veritas
- DS: Downstream
- HP: Hot Pass
- PoD: Probability of Detection
- PoR: Probability of Rejection
- US: Upstream

1.4.2 Definitions

Qualification: The activity, process and analysis that comprise evaluation, testing and analysis of the specific AUT system operated according to a general AUT procedure on a typical industrial application where the specific AUT system is tested for repeatability, stability, reliability and accuracy.

Validation: The activity, process and assessment required to determine and verify whether a specific AUT system exhibiting a qualification status in accordance to this document can be utilised on a project specific application.

2. Qualification Programme

2.1 General

A detailed and agreed Qualification Programme, describing the minimum requirements referenced in this Recommended Practice, shall be established. This Qualification Programme shall contain the following:

— Qualification objectives, i.e. materials, weld process, groove geometries and performance requirement.
(PoD and Sizing accuracy.
— To establish and document environmental and application related tolerances such as temperature consistency, beam and focal law consistency, mechanical stability and electronic interference sensitivity.
— This qualification program is specific to the AUT system, AUT procedure, welding method, and weld bevel configuration being tested.

Qualification to one weld bevel type or one generation of AUT system will not qualify a different bevel type or system than that qualified.

The agreed qualification programme and its implementation shall be supervised and endorsed by a recognised and competent independent 3rd party.

2.2 Extent of Qualification Program

The extent of the qualification programme will reflect the range for which the AUT system is intended to be used, as described in the general AUT procedure. This will include wall thickness ranges warranting essential changes to e.g. transducers, focal law set ups for phased array systems, weld groove and weld process variations commonly experienced. In addition, mechanical variables such as scanner mechanics related to diameter or hybrid solutions will also be considered as essential variables.

The AUT system shall be subject to a full qualification program as described in Sec. 2.3 All data to be used will be developed specifically for this purpose.

Historical qualification data, in compliance to this RP, can be utilised if these data can be clearly identified and supported with all relevant documentation. However the minimum amount of new data shall at least represent 50% of the total minimum required qualification observations as referenced in Section 4 and Appendix A of this RP. Historical data shall be verified by the independent qualification/verification entity to establish relevance to the AUT system and to the qualification objective as defined according to chapter 2.1. The historical data, if found acceptable shall only be permitted if found to fit the statistical model derived by analysing the specifically developed qualification data.

2.3 Qualification Programme

A qualification programme for any AUT system shall comprise the following stages:

1) review of the technical documentation of the AUT system
2) review of the operating methodology for the AUT system
3) review of the Quality Assurance system for development, verification, maintenance and operation of the AUT system
4) review of available performance data for the AUT system (detection abilities and defect sizing accuracy)
5) evaluations and conclusions based on the information made available
6) identification and evaluation of significant parameters and their variability
7) planning and execution of a repeatability test programme
8) planning and execution of a reliability test programme
9) documentation of results from the repeatability and reliability test programmes
10) supplementary NDT and destructive testing
11) analysis of data from the deriving from the above activities. Establish PoD and sizing accuracy.

2.4 Qualification Variables

Variables that will be taken into account for any AUT system qualification include but are not limited to:

— welding method(s) and geometry of welding groove(s)
— base material(s)
— wall thickness limitations
— pipe diameter limitations
— root and cap set-up
— set-up for other channels
— focal law design procedure
— reference reflectors
— temperature consistency
— AUT system including data acquisition and processing
— software version
— AUT Operator/Interpreter training and qualification.
3. Test Welds

3.1 General
Qualification testing shall be performed using test welds containing intentionally induced defects. As the AUT system PoD is the principle description of the AUT system capability, and as such is the main factor to be considered when assessing the specific AUT system suitability for a given application, it is recommended that the induced defects are limited in vertical height, and as minimum not to exceed the assumed maximum height relevant for the weld process used. The minimum number of defects considered necessary to obtain a reliable description of the AUT system overall and weld zone specific PoD and sizing accuracy has been included in tables A-1, A-2 and A-3.

3.2 Requirements to test weld

3.2.1 Welding of test welds
Test welds shall be made from material representative for the intended application(s) of the AUT system and using the actual welding methods and groove geometries. Test welds coupons shall be long enough to allow scanning from either side of the weld and shall have a scribe line in correct position at both sides of the weld.
Defects shall be induced by variation of welding parameters and welding techniques. Copper/tungsten shall be introduced in order to simulate inclusions of these metals when applicable. GTAW may be used to bridge root openings etc. provided the entire GTAW deposit is re-melted by the actual welding process. Defects shall be created by degradation of the welding process, welding parameters and/or welding technique instead of machined or manually induced defects, if possible.

3.2.2 Repair welds
As repair welds will vary in groove geometry it is not advisable to perform a qualification program where the objective is to establish a PoD and sizing accuracy quantification. If the AUT system shall be used for a screening examination of repair welds it is advisable to

3.2.3 Types and number of defects
The type and distribution of defect types, including sizes, shall be typical for the welding methods and weld groove geometries the AUT system is to be qualified for. It is important also to include sizes, which are smaller than, or around those expected using anticipated AUT threshold settings.
The induced defects shall vary in length, height and location. Too close spacing of defects shall be avoided.
Note: Stacked defects do not offer any additional value to the PoD analysis as these due to their nature will differ significantly from the normally assumed PoD height.
In order to show sufficient detection ability (90%) at the required confidence level (95%) the number of defects and their variation in defect types and location is referenced in tables A-1, A-2 and A-3. The recommended no of defects, types and distribution is designed to enable overall statistical significant confidence as well as the ability to make reliable stand alone PoD and sizing accuracy analysis of specific weld zones.

3.3 Supplementary NDT
For all test welds supplementary NDT shall be performed. This includes, as a minimum, radiography according to DNV OS-F101, Appendix D using X-ray and ultra fine grained film, but may also encompass any surface technique (MPE, ECE, ACFM, or PE, as relevant), and manual UT.
It is recommended to perform immersion ultrasonic testing on the welds. Immersion testing should be performed according to section 3.3.1 below.
The results from the supplementary NDT shall be kept confidential.

3.3.1 Immersion Ultrasonic Testing (IUT) of seeded defect girth welds
Immersion testing has several advantages over the AUT tests that are being evaluated. The surface finish of the machined face of the weld ring can be specified to be smooth and flat where the AUT system must contend with uneven surfaces often covered with mill scale and other surface imperfections. Many of the AUT sound paths are relatively long compared to the immersion scan and must bounce off of either the pipe ID or OD surfaces to detect a flaw. The AUT probe is scanned in only 1 direction and must have sufficient beam size to cover its assigned zone. Immersion testing data is generated with probe motion in two directions allowing the use of a smaller beam and still map the entire flaw. These advantages have been shown to have sufficient sensitivity and resolution to detect and characterize flaws of interest in qualification studies. It is recommended that a supplemental surface test method be used to complement immersion testing.

3.3.2 Weld ring preparation
— The cut faces of ring shall be machined flat with a surface finish suitable for the test frequency.
— Reflectors shall be machined into the ring. These serve as confirmation of scan sensitivity and can be used as landmarks for making measurements to locations where sections will be cut.
— The machined reflectors should be located to provide a reflector in both upstream and downstream scan images or use multiple reflectors.

### 3.3.3 Scanning

— Scans shall be performed from both the upstream and downstream faces of the ring to avoid a flaw on the near side of the ring masking a flaw on the far side.
— For narrow gap welds (bevel 5 degrees or less) a zero degree scan is usually sufficient.
— For wide gap welds (bevel greater than 5 degrees) angle beam scans should be performed to reliably detect lack of fusion flaws on the weld prep face.
— Focused probes are recommended to be used to improve resolution. Element size, frequency, and focal length should be selected to produce a depth of field sufficient to cover the area of interest if a single scan is used. Multiple highly focused probes may be required if the depth of field is smaller than the area of interest.
— Scans can be made using either a rotary table or an X-Y raster pattern. X-Y raster pattern is the recommended scanning set-up. For large diameter pipes the rotary table is more efficient.
— Data collection intervals shall be smaller than the beam to ensure that all reflections are recorded.

### 3.3.4 Data Analysis

— C-scan pulse-echo presentations should be made using a time gate to show the area of interest. Back wall echo presentations should also be made to reveal flaws that do not produce strong reflections. These flaws will be revealed as a low amplitude response from the far side of the ring.
— Flaw detection sensitivity and sizing should be demonstrated by scanning a ring with machined reflectors of known sizes at various depths. These scan data are also useful when evaluating weld scan images to estimate flaw size.

### 4. Qualification Testing

The qualification testing will comprise three different test programmes. A repeatability test programme to establish the repeatability capacity of the AUT system, a temperature sensitivity test programme and a reliability test programme to establish the detection and sizing capabilities of the AUT system under different conditions.

The actual extent of testing may deviate from what is specified in the following depending upon the agreed test programme. Once the AUT system has been properly configured, no transducer setting changes or any adjustments shall be made to the AUT system for position changes made during the remaining scanning activities.

#### 4.1 Repeatability Test Programme

The AUT system shall be set-up, calibrated and subject to test runs until deemed ready before resuming the formal qualification.

The test programme shall include the following scans with the calibration block(s) in the horizontal position:

1) one initial scan of the calibration block(s)
2) 10 consecutive scans of the calibration block(s) with the centre of the calibration block(s) in the 12 o’clock position
3) 10 consecutive scans of the calibration block(s) with the centre of the calibration block(s) in the 6 o’clock position. Before the start of the scanning sequence the band may be adjusted if necessary.
   In addition, the following scans shall be performed, depending on the actual application:
4) 3 consecutive scans of the calibration block(s) with the centre of the calibration block(s) in the 2G (vertical) position. Before the start of the scanning sequence the band may be adjusted if necessary.
5) 3 consecutive scans of the calibration block(s) with the centre of the calibration block(s) in the 6G (45 degree) position. Before the start of the scanning sequence the band may be adjusted if necessary.
   Finally the following scans shall be done on one of the nominated defect welds:
6) 3 scans with the band offset 1mm to the DS side
7) 3 scans with the band offset 1mm to the US side.

All scans shall be given a unique number.

Documentation of the test scans shall comprise:
— hard copy and electronic output of the initial calibration scan
— hard copy and electronic output of each scan
— a table showing for each scan the maximum amplitude response of each transducer to its dedicated
calibration reflector and the deviation, preferably in dB, for each scan from the initial calibration scan.

4.2 Temperature Sensitivity Test Programme

The AUT system shall be set-up, calibrated and subject to test runs until deemed ready before resuming the formal qualification.

Typical test weld coupon(s) containing at least 6 clearly identifiable and distinct AUT indications each shall be selected for scanning with the pipe axis in the horizontal position.

The test weld coupon(s) shall after the initial scans be heated to 90°C or another agreed temperature and maintained at this temperature, while the calibration block(s) shall be maintained at environmental temperature.

Total heat exposure for the transducers shall correspond to 15 cycles of scanning on a pipe with the largest diameter the qualification cover, scanned at the normal scanning velocity.

The test programme shall include:

1) one initial scan of the calibration block(s)
2) one initial scan of a non-heated weld(s)
3) one scan of the heated test coupon immediately followed by a scan of the calibration block(s)
4) within 4 minutes repeat one scan of the heated test coupon immediately followed by a scan of the calibration block(s)
5) repeat the sequence for at least 15 cycles.

All scans shall be given a unique number.

Documentation of the test scans shall comprise:

— hard copy and electronic output of the initial calibration scan(s)
— hard copy and electronic output of each scan of the heated test weld coupon(s)
— a table for the scans of the calibration block(s) showing for each scan the maximum amplitude response of each transducer to its dedicated calibration reflector and the deviation for each scan from the initial calibration scan
— a table for the scans of the heated test weld coupon scans showing the maximum amplitude response for each identified indication for each scan.

If the AUT system shows a temperature sensitivity that is found to be unacceptable, the temperature sensitivity test programme can be repeated with agreed altered test conditions.

4.3 Reliability Test Programme

The AUT system shall be set-up, calibrated and subject to test runs until deemed ready before resuming the formal qualification.

The test weld coupons shall be scanned with the pipe axis in the horizontal position. If the AUT system is also to be qualified for scanning with the pipe axis in the vertical position the reliability test programme shall be performed only in this, eventually tests can be performed in both positions.

The welds shall be scanned and all indications above defined thresholds shall be evaluated.

The reference point for start of scanning shall for all scans be the reference point already hard stamped on the test weld coupons.

The identification of scanning directions shall be according to the directions (CW or CCW) already hard stamped on the test weld coupons.

It is strongly recommended to scan each weld twice, preferentially in CW and CCW directions, to improve the number of observations in the POD analysis.

The test programme is recommended to include:

— one initial scan of the calibration block(s)
— one scan of each test weld coupon in the clockwise (CW) direction with re-setting of the band between each scan
— one scan of the calibration block(s)
— one scan of each test weld coupon in the counter clockwise (CCW) direction with re-setting of the band between each scan
— one scan of the calibration block(s).

Scans performed by several teams of operators shall be present in the final data material from the reliability trials. It is recommended that the full test programme described above should be performed twice, with two different sets of operators.
All scans shall be given a unique number indicating weld number, the scan sequence and the scanning direction. All scans shall be performed with a higher sensitivity / lower recording thresholds than expected to be used during normal scanning according to procedure, in order to reveal also not normally reported defects and thereby improve on PoD/PoR description abilities. The scanning of the test weld coupons shall preferably be performed with a reporting threshold setting slightly above noise level.

The exact position of the maximum defect/indication height shall be marked on the test weld coupons on completion of the scans. If agreed, and required during the qualification, that defect length sizing accuracies shall also be determined, defect ends shall be marked in the same manner, according to the length sizing procedure used.

The exact position of the maximum defect/indication height, or defect ends, can be obtained by positioning of the scanner.

Documentation of the test scans shall comprise data tabulated in an Excel spreadsheet format and including the following (all dimensions in mm):

— weld identification/number
— time stamp
— operator name or work ID
— pipe material
— pipe thickness/diameter
— welding method
— groove geometry
— reference reflector used
— defect/indication number and for each defect/indication the dimensional parameters recorded by the AUT system:
  — circumferential position
  — length
  — height (pulse echo only or pulse echo and TOFD)
  — defect depth – through wall distance from the pipe OD to the bottom of the defect
  — transverse location of defects/indications (US, DS, C(entral))
  — maximum amplitude
  — main AUT zone
  — defect type.

In addition the following shall be provided:

— a hard copy and electronic output of the initial calibration scan and hard copy and electronic output of each scan be provided
— AUT viewing software operable under Windows 95/98/2000/NT/XP/Vista
— other NDE reports (MUT, RT, EC, etc.).

5. Destructive Reference Testing

5.1 General

The welds from the reliability test programme shall be subject to Destructive reference Testing (DT) by weld cross sectioning establish the detection and sizing capabilities of the AUT system. Alternatively, other well documented reference techniques may be applied.

The areas for weld cross sectioning will be selected based on the results from the AUT scans and the supplementary NDT. Positions for cross sections shall be agreed upon prior to weld cross sectioning.

The recommended incremental size between sections is 2 mm. Recommended numbers of cross sections for each position in fill and cap are 3 or 5, dependent on expected height variation around maximum value. For root defects, 1 cross section is normally regarded sufficient.

The sectioning to determine the position of defect/indication end or length shall start at the end of the specimen away from the identification markings outside the anticipated defect/indication end and continue in 2 mm increments until a relevant defect/indication has been found.

For random checking only one location will be sectioned.

5.2 Extent of weld cross sectioning

— For determination of detection and sizing capabilities the highest part of the defect, as defined by AUT, shall be selected for “salami” cross sectioning.
— Areas where the AUT shows indications near or below the threshold level shall be selected for sectioning.
— Areas with single defect indications at weld bevel should be preferred as cross section positions. Stacked
defects should be avoided.  
— Areas of uniform defect height should be the preferred positions for cross sectioning.  
— If the supplementary NDT indicates presence of defects not identified in the AUT reports, these areas shall also be selected for sectioning.  
— It is recommended to select random weld areas with no indications from AUT or supplementary NDT for sectioning.

5.3 Marking of test specimens

Prior to removing the test specimen from the test weld coupons each specimen shall be hard stamped as follows:

1) weld number  
2) specimen number  
3) defect indication number  
4) US and DS  
5) a circumferential distance mark giving the clockwise distance from the scanning start point with an accuracy better than ± 1.0mm  
6) centre marks for the highest and lowest part of the defect, as defined by AUT.

The markings 1 through 5 shall be placed outside the area of interest for cross sectioning such that the information will be maintained during the sectioning.

5.4 Marking of Cross Section Locations

Positions for cross sectioning should be marked up using the AUT scanner. Each position for a cross section should preferably be hard stamped close to the weld cap, at the same side (US or DS) for the whole weld. Cross section indication number should be hard stamped. The clockwise scanning direction should be indicated for each location, for instance by a double punch mark 10 mm further along the weld from the cross section position.

5.5 Salami cross sectioning

The salami sectioning shall be performed such that the identification markings 1 through 5 as defined in Sec.5.3 are maintained during the sectioning. The sectioning to determine the position of the maximum height shall follow the plan agreed prior to sectioning with regards to number of sections for each position.

— The specimen shall be machined in increments of 2.0 millimetres or less. Each machined face shall be perpendicular to the pipe surface.  
— Each machined face shall be polished with 800 grit paper and etched with a suitable etchant (Nital for CMn steels) after polishing to 6 micron finish.  
— The defect location, height and depth shall be measured in millimetres with an accuracy better than ± 0.1mm  
— Each machined face shall be documented with a photograph with 5-10x magnification and the photograph shall include:
  — weld number  
  — specimen number  
  — defect/indication number  
  — circumferential position  
  — US and DS side of the weld  
  — a millimetre reference scale.

Documentation of the salami sectioning shall be a table for each test weld coupon and include for each defect/indication:

— Circumferential position of centre for the highest and lowest part of the defect as defined by AUT and as found by sectioning.  
— Length of defect as defined by AUT and as found by sectioning as “no discernable defect”.  
— Height of defect at the point defined by AUT as end of defect.  
— Maximum height of defect as defined by AUT and as found by sectioning.  
— Depth to bottom of defect and remaining ligament as defined by AUT and as found by sectioning.  
— Transverse location (US, DS, C (Central) or US/DS) of defect as defined by AUT and as found by sectioning.  
— Defect type as defined by AUT and as found by sectioning.
6. Analysis of Data

6.1 General
Data analyses shall be performed in accordance with the established and recognized statistical methods such as Nordtest NT Technical Report 394 (Guidelines for NDE Reliability Determination and Description). Recommended statistical technique is regression analysis of hit-miss detection data.

6.2 Qualification criteria
The qualification criteria are according to Clause H300 of DNV OS-F101 (2007), Appendix E related to POD and description of sizing errors, - or alternatively POR. Any AUT system is first deemed to be approved when the qualified PoD value and sizing accuracy value has been found to comply with the application NDT performance demand derived from ECA criteria or other description of quality level are fulfilled.

6.3 Repeatability test programme
The data from the repeatability test programme will be analysed with respect to system repeatability and stability, based on calibration scans and location on the pipe. The maximum deviations for each calibration block position will be considered. A maximum deviation outside ±2dB is not acceptable, according to criteria specified in Clause E109 of DNV OS-F101 (2007), Appendix E. For band offset scans made on deliberate defect weld the criteria shall be that the detection and sizing tolerance shall be equal to the nominal values obtained from optimum scans.

6.4 Temperature sensitivity test programme
The data from the temperature sensitivity test programme will be analysed with respect to the influence of temperature build-up in the transducers over time, i.e. the stability of the system as a function of temperature. The system will be regarded as temperature stable if the maximum amplitude deviations for indications between scans are within the general requirements for repeatability, not more than ±2dB, alternatively, detection and sizing tolerance shall be equal to the nominal values obtained during primary reliability testing.

6.5 Reliability test programme
The data from the reliability test programme shall be analysed with respect to:

— Statistical analysis of the complete set of data from the reliability test programme to establish probability of detection (POD) as function of defect height. A breakdown on position; cap, root and embedded, is recommended.
— For AUT systems where height sizing is a part of defect evaluation, all relevant observations shall be plotted as AUT defined height versus measured height from the validation testing, for evaluation of defect height sizing accuracy. The plots shall include a line representing the 5% fractile against under-sizing (i.e. less than 95% probability of under-sizing). A further breakdown, or check, may be performed to height sizing accuracy related defect type and depth location.
— A probability of rejection (POR) analysis should be performed, as a validation of PoD and height sizing accuracy.

In addition the reporting may include, if relevant:

— A summary of the accuracy in circumferential positioning as function of defect length as defined by AUT versus measured length from the validation testing.
— AUT defect type characterization compared to destructive testing results.
— Accuracy in circumferential positioning as a function of defect depth as defined by AUT versus measured depth of the lowest part of the defect from the destructive testing.
— Accuracy in circumferential positioning as a function of defect actual height and type (surface or buried).
— Accuracy of defect height sizing using amplitude height sizing versus ToFD height sizing. Otherwise, height sizing as used according to procedure will be used, but this approach may serve optimization of height sizing approaches.
— If relevant, a summary of defect length sizing accuracy tabulated and plotted as AUT defined length versus measured length from the validation testing.
— A summary of the defect height variation at the point defined by AUT as end of defect.

6.6 Evaluation of detection and sizing ability
It is recommended to perform POD and POR analysis according to Nordtest NT Technical Report 394. The term Probability of Detection refers to the ratio of defects that will be detected with a certain threshold setting, as a function of defect height. A main concern with this method is to estimate the largest real defect size that might not be rejected at the chosen threshold (the defect height that shows 90% POD at 95% confidence level), and assure that this defect size would stay within the applied acceptance criteria. This value will at the same time represent the smallest defect size that under all circumstances is guaranteed detected at the certain threshold level. It is, however, worth mentioning that the system usually is well able to detect smaller defects than this certain value, but at these sizes a significant number of defects would also be expected to appear as
not detected. Both detection and sizing abilities of defects will have an influence on the PoD-function calculated from the qualification data. This method provides a reliable benchmark for evaluation of the AUT system. The criterion for reliable POR is 85% POR at a 95% confidence level.

POD should be estimated from hit-miss observations as a function of defect height. Hit or miss refers to the level of the defect signal response compared to the reporting threshold of the AUT system. An absent response signal or response below the threshold is regarded as a “miss”, while any response signal above the reporting threshold is a “hit”. The recommended statistical method for obtaining a POD estimate of the observations is binary regression.

The same method should be used for evaluation of POD and POR. The difference between POD and POR is defined by the criteria used on the observations for “hit-miss”. A POD is based on hit-miss by the initial reporting measure at the AUT system, usually echo amplitude or indication in TOFD. The POR is based on hit miss evaluated from the same measure as used in the acceptance criteria, often defect height in mm.

Nordtest NT Technical Report 394, Appendix II, gives formal guidance to this, but in order to obtain a good/relevant PoD/PoR fit different curve forms may have to be tried.

Sizing inaccuracy should be evaluated by an accommodation of the sizing inaccuracy observations to the normal distribution. The 5% probability fraction should be estimated as the one-sided 95% confidence interval against under sizing from the distribution.

The estimated sizing error tolerance value giving 5% probability or less of under sizing should correspond well to the actual observed lower 5% fractile of the sizing error distribution. A significant deviation between estimated and observed values indicates a skewed distribution of sizing errors towards over sizing, which will add unnecessary conservatism to the sizing tolerance estimate. The under sizing tolerance at the observed lower 5% percentile can be used as the sizing error tolerance if it can be sufficiently justified that the height sizing inaccuracy data are not normally distributed.

7. Validity of qualification

7.1 Operational Range Validity

DNV OS-F101 Appendix E Section I 100 states the validity of a qualification. The essential variables listed in DNV OS-F101 Appendix E Section I 201 shall apply with the following clarifications:

1) Root and Cap transducer set-up: This involves the use of hybrid systems where a combination of Phased Array technology and Pulse Echo single or dual or tandem configurations are used.

2) Wall thickness variations will not require re-qualification, provided that the principles for focal law set up do not change. I.e. the number of sequences required to obtain required sensitivity, area of focus and zone height as demonstrated during qualification. Over trace values shall remain within the qualified range.

3) Reference reflectors: It is not permitted to change from FBH or Notches to other type of geometries. Diameter of FBH and notch depth may be reduced provided that necessary area focus and resolution is maintained.

4) Diameter is not an essential variable provided that the mechanical platform for which the transducers are manipulated around the girth weld can be demonstrated to provide equal stability and accuracy as for the nominal scanner platform.

If any of the essential variables referenced in DNV OS-F101 Appendix E Section I 201 are affected it is not necessary to perform a full qualification but a limited validation to verify the ability to detect and size within the nominal values obtained for the system qualification.

7.2 Validity Time

Upon successful completion of the qualification scope referenced within this document it is assumed that the AUT system will remain qualified within the range of qualification for an infinite time period provided that the AUT system remains virtually unchanged, i.e. with no changes that are judged to have an impact on the performance parameters.

The qualification can be validated for use on other projects where the performance parameters differ, if the parameters of the present qualification are regarded relevant and a validation scope is performed. The extent of validation scope has to be agreed upon with client.

8. Certificate of qualification

If a successful qualification is obtained in accordance to this document, a Certificate of Qualification shall be issued by the nominated 3rd party as referenced in 2.1 of this document. The certificate shall reference and contain essential information deriving from the based on the results documented in the specific qualification report valid for this qualification.
9. Project Specific AUT Procedure Validation

9.1 Objective
The objective with the project specific AUT procedure validation is to verify that the qualified AUT system performance can be implemented on project specific applications provided that these remain within the essential variables.

9.2 Scope
Project specific AUT procedure validation shall be performed in order to demonstrate that the project specific AUT procedure can accomplish the qualified performance capabilities. The project specific AUT validation shall normally only comprise the reliability aspects provided that all essential variables remain within reason equivalent to what has been qualified. The reliability aspect shall not include any new PoD analysis. The project specific AUT validation does not replace requirements referenced in OS-F101 Appendix E Section E Field Inspection.

A project specific AUT procedure validation shall consist of the following minimum activities:

— Review of project specific AUT procedure including any pertaining ITP, cal block design reports (WPS), AUT set up files and project specific AUT acceptance criteria including supporting ECA or fatigue reports.
— A compliance assessment of the proposed project specific AUT procedure and AUT system qualification results and pre requisites.
— Verification of hardware and software including calibration block fabrication tolerances.
— Verification of AUT set up on relevant calibration block.
— Review deliberately induced defect weld plan and verify that welds are made with relevant process and geometries as per section 3.2 in this document (minimum 29 defects required for validation).
— Perform supplementary NDT as per section 3.2.3 in this document.
— Perform AUT inspection on deliberately induced defect welds (minimum 29 representative defects).
— Perform weld evaluation at relevant interpretation/reporting threshold, report defect height, depth and length.
— Select minimum 29 ultrasonically independent areas for macro validation testing and perform macro sectioning and reporting as per section 5 in this document.

9.3 Assessment
The performance requirement i.e. AUT system capabilities in terms of PoD and sizing accuracy shall be verified adequate in relation to the smallest allowable weld defect permitted by either ECA/fatigue analysis derived acceptance criteria or other quality standard description. If the AUT system performance results as concluded in the AUT system qualification are not in compliance with the project specific demands then this situation shall lead to a new qualification as per this document.

The project specific AUT procedure shall be verified against the validity range and pre requisites stated in the AUT system Qualification. Reasonable judgment shall be made to minor variations not deemed to impact on PoD and Sizing.

AUT equipment including scanner mechanics, probe/transducer arrays/types and pulsar type shall be essentially equivalent as used during qualification. Software upgrades not impacting on data collection or signal processing are permitted. Changes shall be documented.

The proposed AUT set up shall be verified on the project specific calibration block. Ultrasonic responses from reflectors shall be achieved in an equivalent manner as employed during AUT system qualification.

The number of test welds containing deliberately induced defects shall be sufficient to ensure that a minimum of 29 representative defects distributed as per tables…… can be obtained. The defects shall exhibit dimensions on or close to the smallest allowable defect as per the project specific acceptance criteria.

Performance of the AUT scanning shall be conducted at ambient temperature unless otherwise agreed and at project specific reporting threshold in compliance with pre requisites given by the AUT system Qualification report. Scanning shall be performed with nominal band setting unless otherwise agreed. Reverse scanning shall be performed unless otherwise agreed. All relevant AUT indications exceeding noise level shall be reported on a suitable format containing all relevant signal information.

A minimum of 29 ultrasonically independent locations shall be selected for validation testing by macro sectioning in accordance to section 5 of this document. The selection criteria shall be as follows:

Defect indications exhibiting dimensions equivalent or larger than the AUT system PoD but smaller or equivalent to the project specific smallest allowable defect as identified in the project specific acceptance criteria adjusted for sizing accuracy.

One volumetric indication shall be included for verification.

A summary report containing all collected data shall be prepared and a comparison between supplementary NDT, AUT and macro section data shall be made.
The purpose of the validation is not to perform a PoD analysis but to verify that the project specific AUT procedure capability is adequate for detection of the smallest project specific critical defect. This is obtained by demonstrating detection of all 29 defects and that these 29 defects has been sized and positioned within the qualified accuracy. If this is achieved, the project specific AUT procedure is validated and shall be accepted.
APPENDIX A
TEST WELD DEFECT MATRIX

Recommended number and types of defects for a qualification.

Table A-1  Number of deliberate flaws for GMAW J prep welds

<table>
<thead>
<tr>
<th>Defect type group</th>
<th>No of Flaws</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>29 (7*)</td>
<td>If root channels and HP/radius channels are unique it may be possible to combine flaws from root and HP and reduce the total no in this area.</td>
</tr>
<tr>
<td>HP/radius</td>
<td>29 (6*)</td>
<td></td>
</tr>
<tr>
<td>Fill</td>
<td>29 (7*)</td>
<td></td>
</tr>
<tr>
<td>Cap</td>
<td>29 (7*)</td>
<td>This flaw group shall also encompass subsurface flaws with bottom part maximum 5 mm from surface</td>
</tr>
<tr>
<td>Cu</td>
<td>2</td>
<td>Cu type flaws shall not be included in PoD analyses but are included to demonstrate detection and recognition</td>
</tr>
<tr>
<td>Inter run</td>
<td>2</td>
<td>Inter run flaws shall not be included in PoD analyses but are included to demonstrate detection and recognition</td>
</tr>
<tr>
<td>Cluster porosity</td>
<td>2 (1*)</td>
<td>Cluster porosity flaws shall be made as small as possible and then in the upper regions of the cross section. Cluster porosity shall not be included in the PoD analyses but are included to demonstrate detection and recognition.</td>
</tr>
<tr>
<td>Total Min No of Flaws</td>
<td>122 (93)</td>
<td>Ref Root/HP comment</td>
</tr>
</tbody>
</table>

* Number of defects for project specific AUT procedure validation

Table A-2  Number of deliberate flaws for SAW X prep welds

<table>
<thead>
<tr>
<th>Defect type group</th>
<th>No of Flaws</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 OD Cap</td>
<td>29 (9*)</td>
<td>Zone 1 OD is encompassing the cross section from OD cap to top of CP region. This group shall include min 10 sub surface flaws with bottom part minimum 5 mm from cap</td>
</tr>
<tr>
<td>Zone 2 CP (root)</td>
<td>29 (9*)</td>
<td>Flaws shall be located at the cross penetration including areas where a shift in groove geometry is made. Flaws to be made on the CP, below and over CP</td>
</tr>
<tr>
<td>Zone 3 ID Cap Internal weld</td>
<td>29 (9*)</td>
<td>This zone shall include surface and sub surface flaws</td>
</tr>
<tr>
<td>Cu</td>
<td>2</td>
<td>Cu type flaws shall not be included in PoD analyses but are included to demonstrate detection and recognition</td>
</tr>
<tr>
<td>Cluster porosity</td>
<td>2 (2*)</td>
<td>Cluster porosity shall be included for demonstration and recognition only. Not be included in PoD analyses.</td>
</tr>
<tr>
<td>Total Min No of Flaws</td>
<td>91</td>
<td></td>
</tr>
</tbody>
</table>

* Number of defects for project specific AUT procedure validation.
### Table A-3 Number of deliberate flaws for SMAW/FCAW V prep welds

<table>
<thead>
<tr>
<th>Defect type group</th>
<th>No of Flaws</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>29 (9*)</td>
<td>This group of flaws shall include flaws extending into HP</td>
</tr>
<tr>
<td>Fill</td>
<td>29 (9*)</td>
<td>This group assumes lack of side wall fusion or slag entrapment located on bevel/weld metal transition</td>
</tr>
<tr>
<td>Cap</td>
<td>29 (9*)</td>
<td>This flaw group shall also encompass subsurface flaws with bottom part maximum 5 mm from surface</td>
</tr>
<tr>
<td>Cu</td>
<td>2</td>
<td>Cu type flaws shall not be included in PoD analyses but are included to demonstrate detection and recognition</td>
</tr>
<tr>
<td>Slag/Inclusion weld centre line</td>
<td>4 (1*)</td>
<td>Flaws to be located at the weld centreline. Not to be included for PoD analyses but for demonstration of detection and recognition.</td>
</tr>
<tr>
<td>Inter run (Only if deemed relevant for weld process)</td>
<td>2</td>
<td>Inter run flaws shall not be included in PoD analyses but are included to demonstrate detection and recognition.</td>
</tr>
<tr>
<td>Cluster porosity</td>
<td>2 (1*)</td>
<td>Cluster porosity flaws shall be made as small as possible and then in the upper regions of the cross section. Cluster porosity shall not be included in the PoD analyses but are included to demonstrate detection and recognition.</td>
</tr>
</tbody>
</table>

**Total Min No of Flaws** 97 (91*)  
Ref: Inter run comment

* Number of defects for project specific AUT procedure validation.