DEP SPECIFICATION

AUTOMATED ULTRASONIC INSPECTION (AUT) OF GIRTH WELDS FOR CARBON STEEL AND CRA LINED PIPELINES, FLOWLINES AND CATENARY RISERS

DEP 37.81.40.32-Gen.

February 2014

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

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PART I CARBON STEEL PIPELINES, FLOWLINES AND CATENARY RISERS

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the use and interpretation of automated ultrasonic inspection (AUT) systems for the inspection of girth welds in carbon steel pipelines, flowlines and catenary risers, as well as CRA welds. Required accuracy of the AUT system and interpretation requirements are defined in this DEP for Category A, B or C welds (to be specified by the Principal).

Part I of this DEP covers inspection of welds in carbon steel pipelines, flowlines and catenary risers using carbon steel weld filler metal.

Part II covers inspection of welds applicable to CRA lined carbon steel pipelines, flowlines and catenary risers with CRA weld filler metal, and is written in the form of amendments and supplements to Part I. All clauses of Part I not modified by Part II remain valid as written.

Qualification of automated ultrasonic inspection (AUT) systems and inspection procedures are outside the scope of this DEP, but are covered in DEP 37.81.42.35-Gen.

This is a revision of the DEP of the same number dated February 2012; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas exploration and production. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

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1.3.2 Specific definitions

Term	Definition
AUT-Contractor	The AUT Contractor is the party that carries out the AUT inspection and, if required, manual ultrasonic inspection. The AUT-Contractor can be hired directly by the Principal or subcontracted by the Contractor. The AUT-Contractor is responsible for the delivery of the AUT inspection, AUT operators and necessary equipment and documentation for the qualification and production inspection of the AUT system, including the specified reporting. If the AUT-Contractor is contracted by the Contractor, and this DEP states that review and/or approval by the Principal is required, then this means that Contractor's review and/or approval is also required, even if not stated explicitly in this DEP.

1.3.3 Abbreviations

Term	Definition
AFC	Approved for Construction
AUT	Automated Ultrasonic Testing and Inspection
CL	Cold Lap
CRA	Corrosion Resistant Alloy
DSAW	Double Submerged Arc Welded
ECA	Engineering Critical Assessment
FBE	Fusion Bonded Epoxy
FBH	Flat Bottom Hole
FSH	Full Screen Height
GMAW	Gas Metal Arc Welding
HAZ	Heat Affected Zone
ID	Inside Diameter
IP	Inadequate Penetration
IUT	Immersion Ultrasonic Testing
LOF	Lack of Fusion
MOC	Management of Change
MT	Magnetic Particle Testing
NDE	Non Destructive Examination
OD	Outside Diameter
QC	Quality Control
PA	Phase Array
PT	Penetrant Testing
RT	Radiographic Testing
SCR	Steel Catenary Riser
STT	Surface Tension Transfer
TOFD	Time of Flight Diffraction
TOF	Time of flight or transit distance
WT	Wall thickness

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1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets ( ). Other documents referenced by this DEP are listed in (Part III).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a minor revision of the DEP of the same number dated February 2012. The following are the main, non-editorial changes:

Section/Clause	Change
Part I, 1.6	Updated feedback process (comments).
Part I, 3.1	Revision of Table 1, based on recent qualification of AUT systems and a similar change in Table 2 in DEP 37.81.42.35-Gen.

In addition to the above, a number of changes have been made in (3), (4), (8) and (9) as the result of learnings from several recent deepwater projects. These changes are too numerous to list here.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the “Give feedback” link, fill in the online form and submit.
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DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com.

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

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2. APPLICATION OF THIS DEP

This DEP may be used independent of the standard to which the facility (flowline, pipeline or catenary riser) has been, or is being, purchased.

3. QUALIFICATION OF AUT SYSTEMS FOR FIELD INSPECTION

3.1 GENERAL

AUT systems and inspection procedures shall be qualified in accordance with DEP 31.81.42.35-Gen.

The Principal for the project shall specify the required accuracy of the AUT systems used for field inspection as Category A, B or C in accordance with Table 1.

Table 1A Default uncertainty and standard deviation requirements for a qualified AUT System (pipe wall thickness 27 mm or less)

Category	Application	Defect type	Defect height threshold level (mm)	Maximum standard deviation mm	Maximum uncertainty (mm)
A	SCR[5]	Root[1,7]	0.3	0.3	0.8
		Cap[2]	0.3	0.4	1.0
		Embedded[4]	0.8	0.8	1.5
B	Flowlines and pipelines[6]	Surface[3,7]	0.5	0.6	1.0
		Embedded[4]	0.8	1.0	1.5
C	Good workmanship	Surface[3,7]	0.5	1.0	1.5
		Embedded[4]	1.0	1.5	1.5

1. Accuracy requirements apply to defects completely contained within a 1.5 mm zone at the ID.
2. Accuracy requirements apply to defects completely contained within a 2.0 mm zone at the OD.
3. Accuracy requirements apply to defects completely contained within a 1.5 mm zone at the ID and 2 mm zone at the OD.
4. Embedded defects are all defects not defined by 1, 2 and 3 above.
5. The Principal may also specify other welds to be included in Category A, e.g., reeled welds or fatigue-sensitive welds.
6. Typically, Category B welds are welds for which an Engineering Critical Assessment is conducted to determine allowable defect dimensions (through-wall height and length) that may exceed the allowable defect dimensions of Category C.
7. For clad closure welds, the definition “surface” at the ID shall be no less than the thickness of the clad material.

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Table 1B Default uncertainty and standard deviation requirements for a qualified AUT System (pipe wall thickness 27.1 mm to 35.0 mm)

Category	Application	Defect type	Defect height threshold level (mm)	Maximum standard deviation mm	Maximum uncertainty (mm)
A	SCR[5]	Root[1,7]	0.5	0.7	1.0
		Cap[2]	0.5	0.7	1.0
		Embedded[4]	0.8	0.8	1.5
B	Flowlines and pipelines[6]	Surface[3,7]	0.5	0.9	1.2
		Embedded[4]	0.8	1.0	1.5
C	Good workmanship	Surface[3,7]	0.5	1.1	1.6
		Embedded[4]	1.0	1.5	1.6

1. Accuracy requirements apply to defects completely contained within a 1.5 mm zone at the ID.
2. Accuracy requirements apply to defects completely contained within a 2.0 mm zone at the OD.
3. Accuracy requirements apply to defects completely contained within a 1.5 mm zone at the ID and 2 mm zone at the OD.
4. Embedded defects are all defects not defined by 1, 2 and 3 above.
5. The Principal may also specify other welds to be included in Category A, e.g. reeled welds or fatigue-sensitive welds.
6. Typically, Category B welds are welds for which an Engineering Critical Assessment is conducted to determine allowable defect dimensions (through-wall height and length) that may exceed the allowable defect dimensions of Category C.
7. For clad closure welds, the definition “surface” at the ID shall be no less than the thickness of the clad material.

The Principal may elect to use previous experience and qualification results when considering the qualification of the AUT-Contractor’s AUT systems and inspection procedures for different weld designs, inspection methods, or changes in inspection equipment. However, a performance check, as specified in (3.2) of this DEP shall be performed even if no further qualification is required.

3.2 PERFORMANCE CHECK

A procedure performance demonstration shall be performed for every project. Contractor shall submit to Principal for review a performance demonstration plan detailing the activities, schedule and reporting formats. The performance demonstration shall be generated and the results reported to Principal prior to use on Fatigue String, PCP, Welder Qualification and production welds. In the procedure performance demonstration, it is of particular importance to demonstrate the ability to consistently detect and size near-ID and near-OD defects, as outlined in (9.17) of this DEP. Prior to the commencement of the performance check activities, the Contractor shall submit to the Principal all documentation defined in Section 13.5 for review and comment as per the project document review guidelines.

The demonstration process shall be as follows:

a) At least two welds each containing between 10 and 15 defects shall be prepared by the Contractor from actual production pipe material samples for each welding procedure specification. The defects shall be equally spread on the outer zone, the volumetric zone and the root/hot pass. At least 5 defects shall be located in both

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the critical root/hot pass area and the critical cap zone (outer 3 mm of the weld). Contractor shall submit defect maps for Principal approval prior to seeded defect fabrication. Defect seeding the root region shall utilize natural seeding techniques, artificial techniques shall not be used within 3 mm of the ID surface.

b) An AUT inspection shall be carried out on the test pipes according the proposed AUT procedure, within the detailed temperature ranges, and the results shall be documented. Only equipment and procedures proposed for production inspection shall be used for this inspection.

c) Manual UT inspection shall be carried out on the test pipes according to the proposed Manual UT procedure, within the detailed temperature ranges and the results shall be documented. Only equipment and procedures proposed for production inspection shall be used for this inspection.

d) Radiographs shall be made of the welds and the results documented.

e) Metallurgical examination to determine defect height shall be carried out in the more critical root/cap areas where inaccuracies of 1.0 mm are needed

f) A comparison shall be made between Pulse echo (P/E), Time of flight diffraction (ToFD), Manual UT and radiographic analysis to calculate defect height and length in the girth weld

g) Differences in the reported values between AUT, Manual UT and RT inspection shall be noted. At the Principal's option destructive testing shall be performed to verify reported defect sizing.

h) Additional data acquisition testing shall be performed on a single performance check coupon to ensure data averaging or "data fill" functions are not enabled.

i) The Principal may also require other NDE techniques efforts, such as immersion ultrasonic testing, for examination of the welded samples and comparison to the UT results.

The performance check is only an indication of the performance of the system based on earlier inspections. Inaccuracy should be given by a full qualification investigation.

The performance check is a verification of project specific AUT system performance within the accuracy values defined by full AUT system qualification. Verification results exceeding qualification limits may require further performance testing, qualification or require the implementation of project specific interpretation guidelines as defined by the Principal. Project NDE procedures shall not be approved for use in production until the performance check activity has been completed and the final performance check report issued by the Contractor to Principal for review and comment as per the project documentation review guidelines.

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4. AUT SYSTEM

4.1 GENERAL

AUT inspection shall be performed with a mechanized system that utilizes pulse-echo and/or pitch-catch focused transducers with zoned inspections and Time of Flight Diffraction (TOFD) techniques. The AUT system shall have the capability to distinguish between surface, near surface (ID and OD) and embedded defects and demonstrate the ability to accurately size length and vertical height of indications with a resolution compatible with the applicable acceptance criteria.

The AUT system shall be capable of detecting both longitudinal and transverse defects in the weld. Detection and sizing of transverse defects may be omitted from the AUT inspection, subject to approval by the Principal if:

- The welding process used has no industrial evidence of producing transverse defects. Manual UT shall be used to supplement AUT inspection during the AUT performance check, the weld procedure qualification, welder qualification and any fatigue sample fabrication , to demonstrate the proposed welding process does not inherently produce defects in the transverse orientation
- There is sufficient evidence that transverse defects will not be produced under the conditions of the weld procedures that will be used.

The system shall be designed with sufficient beam overlap to assure 100 % coverage of the weld and HAZ and shall include a fully automated recording system to indicate the location of imperfections and the effectiveness of the acoustic coupling.

The AUT-Contractor may propose another ultrasonic approach for approval by the Principal.

4.2 ULTRASONIC SYSTEM

The system shall provide an adequate number of inspection channels to ensure the complete volumetric and Heat Affected Zone (HAZ) examination of the weld through thickness. The instrument shall provide a linear “A” scan presentation for each channel selected. Instrument linearity shall be determined according to the procedures detailed in EN 12668-1, within six months of the intended end use date. The AUT-Contractor shall retain a copy of the calibration certificate. Instrument linearity shall be such that the accuracy of any indicated amplitude is within 5 % of the actual full scale amplitude, if amplitudes exceeding 100 % FSH are defined in the AUT General Procedure, instrument linearity shall be performed for the entire proposed amplitude range. This shall apply to both linear and logarithmic amplifiers.

Each inspection channel shall be selective for; pulse-echo or through transmission mode, gate position and length for a minimum of two gates, and gain. Recording for all channels shall be 0–100 % of full screen height for simple amplitude and transit time recording and shall be from 0–100 % for B-scan or “mapping” type recording of data. Clipping of low amplitude signals shall not be permitted. Two recordable signal outputs per gate shall be available, being either analogue or digital and representative of signal height and time of flight. These will be suitable for recording on a multi channel recorder or computer data acquisition software display. Frequency filtering shall not be used without Principal approval.

4.3 RECORDING SYSTEMS

A distance measuring circuit or device suitable for connection to the recorder or acquisition system shall be used to provide a means of electronically determining circumferential weld distance to an accuracy of ±1 cm or better, as required by the Principal, over the circumference of the weld. Programmed scan lengths shall be sufficient to ensure all probes will travel the maximum circumferential distance required for a pipe having a diameter with the maximum tolerance allowed by the Principal’s specification. For

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equipment with encoders travelling on a track or welding guide-band, a correction factor shall be incorporated to ensure the circumferential distance recorded on the chart corresponds to the transducer position on the pipe OD surface. The recording or marking system shall clearly indicate the location of discontinuities relative to the marked starting position of the scan, with ±1 cm accuracy. There shall be recordings from each transducer for weld discontinuities and confirmation of the acoustic coupling arranged on the chart or display in a manner acceptable to the Principal.

All data channels shall be sampled and recorded in 1 mm steps for every 1 mm of weld circumference. Software averaging over more than 1 mm length to fill in missed data is strictly prohibited.

B-scan or "mapping" displays shall be used for volumetric defect detection and characterizations. Thresholds for "mapping" of the root, cap and volumetric channels shall be set no more than 5 % above background noise.

4.4 COUPLING

The coupling shall be obtained by using a medium suitable for the purpose. An environmentally safe wetting agent may be required to enhance acoustic coupling. No residue shall remain on the pipe surface after the liquid has evaporated. For examination where pipe cool-down may be required after welding, water spray or other agents may be used with Principal approval.

Coupling monitoring shall use thru-transmission through the weld volume. When diffracted longitudinal wave mode is utilized for thru the weld volume coupling monitoring, it should be demonstrated that no other signal with equivalent or higher amplitude appears in the later portion of the monitoring gate using opposite pairs of transducers for each zone. For each zone pair instrument gain shall be adjusted to produce a transmittal signal to 40 % FSH (recordable threshold level) when utilized in the thru- transmission mode. 8 dB shall be added to bring the signal to the reference level. Coupling response below 40 % of reference shall represent a loss of coupling that shall be addressing per the AUT testing requirements. An examination of the calibration standard with its surface wiped dry shall produce a record showing an absence of the coupling recording signal. Increase in added gain to offset effects of weld geometry or pipe surface conditions shall be used only with Principal authorization.

4.5 TRANSDUCERS

Prior to the start of field weld inspection, details of the types and numbers of transducers shall be specified. If the AUT-Contractor proposes to use phased array (PA) transducers, separate requirements for use of PA are defined in (4.8).

Once agreed, there shall not be any transducer or design changes without prior agreement.

Each transducer shall be marked with a method to identify the Manufacturer's name, transducer type, exit point, incident beam angle or refracted beam angle for a specific wedge/steel velocity ratio, frequency, and crystal size. The transducer array design shall be specific to the project and weld bevel design where the inspection is to be performed. All search units shall be contoured to match the curvature of the pipe surface. The following transducer parameters shall be documented following the procedures defined in EN 12688-2, and shall be submitted to the Principal upon request.

a) Beam Angle - For beam angles less than or equal to 45°, the measured angle shall not differ by more than 1.0°. For beam angles greater than 45°, the measured angle shall not differ by more than 1.5°. The beam angle for TOFD shall be within ± 5°.

b) Beam Size - The vertical dimensions of the beam at the target shall be within 20 % of the design height specified. The horizontal dimension of the beam at the target shall not be greater than two times the vertical dimension of the beam. The target is defined as the point along the beam axis where the inspection is to be performed. In the case of a focused element the target shall fall within the -6 dB

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working range distributed across the focus. Beam height measurements shall be taken at five points along the -6 dB working range.

c) Overall Gain - The overall gain shall be at least 40 dB.

d) Index Point - All transducers shall have a clearly defined index point.

e) Squint - The squint angle shall not exceed 1.5° for single crystal transducers or 2° for twin crystal transducers.

f) Longitudinal Angle Beam - The longitudinal angle beam shall be at least 35 dB weaker than the shear wave beam measured at a range of 100 mm.

g) Surface Waves - Surface waves shall be at least 34 dB weaker than the shear wave, for beam angles less than or equal to 64°. For angles greater than 64° they shall be at least 24 dB weaker, measured at a range of 100 mm.

h) Side Lobes - Side lobes shall be at least 20 dB weaker than the main beam, except for angles greater that 64° where they shall be at least 15 dB weaker.

i) Subsidiary Maxima - Any fluctuations in the echo amplitude shall not exceed that caused by interference caused by excessive signal to noise.

j) Pulse Shape - The pulse shape shall be single peaked with any secondary peaks in the tail of the pulse at least 20 dB less than the peak.

k) Frequency - The operation frequency shall be within ± 10 % of the nominal frequency.

l) Pulse Length - The pulse length shall not exceed 2.5 µsec between points on the rectified pulse at 10 % of peak amplitude.

m) Signal to Noise - For all transducers except creeping wave transducers, the noise shall be at least 20 dB weaker that the signal from the reference reflector at the target distance. For creeping wave transducers the noise shall be at least 16 dB weaker than the signal from the reference reflector at the target distance.

n) Transducer face wear - Scores in the transducer wear face that may cause local loss of contact or which exceed 0.5 mm require transducer replacement.

4.6 TOFD SYSTEM

TOFD techniques shall be included as part of the data acquisition and display to improve characterization and sizing. TOFD techniques shall augment pulse-echo techniques but shall not replace pulse-echo techniques unless the TOFD display represents a potential defect that may not be fully represented by the pulse/echo data due to defect orientation.

TOFD recording systems shall be capable of a 256 level greyscale display and shall be capable of recording full R-F waveforms for the TOFD transducer pairs.

TOFD shall have a minimum frequency of 7.5 MHz for Category B and C welds. For Category A welds, the inspection requires a minimum TOFD frequency in the range of 10-15 MHz, with the minimum frequency dependent on specific project acceptance criteria. Use of frequencies different from those defined above shall be subject to approval of the Principal with additional demonstration.

4.7 POWER SUPPLY

There shall be no loss of inspection data as a result of a possible power failure.

4.8 PHASED ARRAY INSPECTION

If the AUT-Contractor uses phased array (PA) technology instead of dedicated focused probes for each zone inspection, the following additional requirements shall apply:

a) The PA system shall, as a minimum, have the same quality performance as the conventional AUT system as described in this DEP.

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b) Before start of initial system configuration, a dead element software check shall be performed.

c) Within the probe as a whole, there shall be no more than three dead elements that would be used in any focal laws. For any one focal law, there shall be no more than two adjacent dead elements in the focal law.

d) Once the initial system calibration is configured with the appropriate settings for channels, timing and gains, these values shall become the reference system parameters. For pipe-to-pipe calibration standards, the complete system symmetry shall be verified side-to-side by scanning the calibration standard first from one side, then from the opposite side. The responses to corresponding reflectors shall be within ±3 dB for all channels. This check is required to be performed only once at initial start-up. Prior to the performance of this check the calibration block ultrasonic verification data shall be reviewed. If the manual ultrasonic verification reveals side to side measurements that will impact the successful completion of this check the Principal shall be notified.

e) The reference system parameters shall be locked into the system, with only minor adjustment allowed. (Minor adjustments are defined as follows; cumulative gain adjustments are limited to less than 2 dB, and any focal law channel shift shall limit the inspection change to 1.5° or less). Reference parameters shall only be changed by an AUT supervisor with approval of the Principal. All system parameters shall be documented via hard copy after any changes.

f) During system calibration checks, any channels requiring 2 dB or more of gain adjustment from the reference value requires that the full system and dead element check be performed. Any system changes that require a focal law channel change(s) resulting in an angle change greater than 1.5° requires a full system dead element check.

g) The dead element check shall be performed at least once every 12 hours.

h) The AUT-Contractor shall implement independent TOFD channels at 7.5 MHz (Category C) or 10 MHz (Category A and B). Use of the PA probe to produce the TOFD is not acceptable. AUT-Contractor may propose additional ToFD channels with adjusted probe separation to focus on specific areas of the weld if there is a benefit of improved resolution.

i) Coupling monitoring shall require that elements in groups of no more than ten be used in shear wave thru-weld transmission with reception on the opposite weld side to mimic the zonal coupling defined for dedicated focused probes. All inspection zones shall be included in the thru-weld coupling verification. Thresholds and gain setting shall be the same as for dedicated probes. It should be noted that coupling losses with PA probes may impact more than one zone.

j) The AUT-Contractor shall implement a quality program whereby the focal law values shall be locked. Changes are only allowed by the AUT supervisor with approval from Principal. Whenever there are changes, a log of all focal laws shall be printed for the QA records. Any significant changes in focal laws require a complete check of system component to verify integrity of elements and all other components.

k) Wall thickness and/or pipe diameter parameters have greater impact on defect sizing with PA probes compared to focused probes. The qualification of a PA system shall address these parameters and establish height and length accuracy for applicable wall thickness and diameter.

l) As a note of caution, over focusing of PA probes is possible wherein very small beam spot sizes can be created, and these small spot sizes can result in decreased capability in defect sizing and detection.

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