Variability of Instrument and Search Unit Combinations

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Question Asked by NRC

- What is the justification for the statement in ASME Code Section XI, Div 1, Appendix VIII-4100, 2002 Addenda, that:

"Components of the same manufacturer, and model or series, are substitutable without further consideration"?

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System Variability

- Instrument and Search Unit variability have long been recognized as a key essential variables.
- Instrument Pulser and Receiver
  a. Sensitivity
  b. Pulser output voltage
  c. Horizontal and vertical linearity
  d. Center frequency and bandwidth

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System Variability

- Search Unit
  a. Incident angle
  b. Sensitivity
  c. Center frequency and bandwidth
- Cable
  a. Type
  b. Length
  c. Number of connectors

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Calibration

- Calibrations before each use standardizes:
  - Sensitivity
  - Pulser out put voltage

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Instrumentation Checks

- Horizontal and vertical linearity
  - Is indicative of proper instrument operation
- Search Unit incident angle
  - Subject to wear (Held within 3 degrees)
- Cables
  - General system loop response will indicate that cables are operating properly. No signal and high or intermittent noise is indicative of a cable problem.

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Center Frequency & Bandwidth

- Instrument
  - Bandwidth is normally 5 or more times larger than the search unit
  - Problems with bandwidth or center frequencies are generally catastrophic i.e., instrument fails to function.
  - Controlled by passive components which fail open or short

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Center Frequency & Bandwidth

- Search Unit
  - Frequency is controlled by the physical dimension of the element which does not change
  - Bandwidth is controlled by the materials used and bonding of the element to the backing member and the front face

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Center Frequency & Bandwidth

- Failure of Instrument and Search Unit
  - Is immediately evident by a much reduced response, ringing and system noise.
  - Calibration using qualified instrument setting is no longer possible.

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Code Perspective

- A Code inquiry and a code revision to clarify this issue has been reviewed, approved and published
- This same approach is also used for Steam generator qualifications by (SGMP) and by the Swedish SQC for procedure and personnel qualifications.
- This interpretation is internationally accepted

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Experience

- There have been 93 piping qualification sessions since 1994. Each session contains 10 to 15 candidates. Each candidate uses a unique instrument.
- 5497 piping performance demonstrations have been completed.
- Assuming that a minimum of 20% of these use a unique instrument would indicate that 1000 unique i.e., different serial numbers, instruments have been used. Likewise we estimate that 10,000 unique search units have been used.

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Experience

- In these 5497 demonstrations using 1000 different instruments and 10,000 search units:

  We have observed that properly functioning equipment has not caused failure of the candidate or procedure in any performance demonstration.

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Qualifications

- PDI Table 1. Lists the qualified instrument and search units. These qualifications are specific to procedure, access and application.
- PDI Table 2. Lists the qualified instrument settings for each qualified instrument.
- A user name and pass word for viewing Table 1 and 2 can be arranged by contacting jarendt@epri.com.

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Instrument and Search Unit Combinations

PROCEDURE - PDI UT-2 **MATERIAL - Austenitic Piping**

MODEL	MANUFACTURE	COMBINATION	CUMULATIVE TOTAL
SONIC 136	STAVELEY	225	225
USK 7D	KRAUTKRAMER	101	326
EPOCH II	PANAMETRICS	58	384
USN 50	KRAUTKRAMER	53	437
SONIC 137	STAVELEY	52	489
EPOCH III	PANAMETRICS	49	538
USN 52L	KRAUTKRAMER	40	578
EPOCH IIB	PANAMETRICS	40	618
USN 52R	KRAUTKRAMER	29	647
SONIC 1200S	STAVELEY	20	667
USN 60	KRAUTKRAMER	15	682
MASTER 335	SONATEST	11	693
SONIC 1200 HR	STAVELEY	9	702
EPOCH 4	PANAMETRICS	8	710
USN 52	KRAUTKRAMER	6	716
MASTER 330	SONATEST	6	722

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Conclusions

- Each instrument and search unit combination has been demonstrated.
- Instruments and search units are calibrated before each use.
- Horizontal and vertical linearity as well as search unit angle are checked.
- No demonstration failures have been observed as a result of using functioning and calibrated instruments.
- The replacement of the same make and model is accepted by 3 international consensus standards organizations, (ASME, SQC and SGMP).

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White Paper

Variability of Instrument and Search Unit Combinations

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Question

The NRC has asked the question:

> *What is the justification for the statement in VIII-4100, 2002 Addenda, that "Components of the same manufacturer, and model or series, are substitutable without further consideration"?*

The following is a description of the PDI and other international organizations position on this subject.

Variability, Calibration and Instrumentation Checks

It has long been recognized that ultrasonic systems have a certain degree of variability. The ASME Code and other requirements documents have always placed calibration requirements and instrument requirements on examination procedures to minimize the impact of these variables.

Sources of variability considered include:

Instrument Pulser and Receiver

a. Center frequency bandwidth
b. Sensitivity
c. Pulser output voltage
d. Horizontal and vertical linearity

Search Unit

e. Incident angle
f. Sensitivity
g. Center frequency and bandwidth

Cable

h. Type
i. Length
j. Number of connectors.

System calibration will standardize examination sensitivity variables b, c, and f. Instrument checks will assure that items d, and e are limited to acceptable values. Frequency and bandwidth items a. and g. are not normally measured during field applications. Cable parameters h, j, and i are qualified as a part of the procedure and personnel demonstrations.

The frequency and bandwidth of a normally operating system do not change with age or use. Any major change in these parameters will be reflected in drastically reduced sensitivity or increased noise. The bandwidth of modern instruments may be as much as 15 to 20 MHz. This is much larger than bandwidth of the search unit (generally less than one MHz) for the frequencies that are used for ultrasonic inspection of nuclear components. Small changes in the instrument center frequency will have little or no effect on the system bandwidth.

The search unit is a resonant device and the center frequency is determined by its physical size, which does not change. The bandwidth is a function of the construction techniques that rely on bonding of the active element to a backing material and a protective front face or quarter wavelength-matching layer. Failure of either of these bonds will result in a near total loss of sensitivity or a high level of noise. These conditions are immediately obvious to the operator. The most probable variation in search unit performance will result from wear of the contact surface which will result in an angle change which is measured during system calibration and must be within 3° of the specified angle.

The basic system operating characteristics are qualified as a part of Appendix VIII personnel and procedure qualifications. It is expected and it has been our experience that any change that would effect the system center frequency or band width would be immediately obvious during system checks and calibrations.

Code Perspective

It was never the intent of the ASME Code that each and every component be characterized. The requirements of VIII-4100 were intended only for the cases where components of a different manufacture, make or model were intended to replace the qualified manufacture make or model. The difference between exchange and replace is defined succinctly in Ref. (1) as follows:

> **Exchange** = To use one of the same property as the qualified NDT – system.
>
> For example, if an NDT instrument is specified by the make (manufacturer) model and type number in the qualified NDT system then any instrument of the same make, model and type number can be used with the qualified NDT-system.
>
> **Replace** = to use a property of a similar type as the qualified NDT system.

> For example, if an NDT instrument is specified by the make (manufacture), model and type number in the qualified NDT system and an alternative is proposed where any of the following, make (manufacture), model and type number is different the essential variable is considered to be replaced.

The SQC requirements (1) the PWR Steam Generator Examination Guidelines (2) and Appendix VIII (3) all take a similar approach regarding exchanges and replacements:

> An exchange requires that the identity of the component be established through documentation and that a system calibration is required to establish that the system is operating in the same manner as when it was qualified a normal system calibration before and after the examination is sufficient.
>
> A replacement requires either a new qualification be performed or the exchanged component or the system as a whole can be characterized to demonstrate that the new component is performing within defined limits of the original system configuration.

Each of the three international consensus standards relies on the OEM manufacturing tolerances and 10CFR50 Appendix B or similar national standard quality assurance programs to control measuring and test equipment operability and repeatability. In the case of exchanges that is all that is required. In the case of replacements additional requirements are placed on the replacement items that are more stringent than normal OEM tolerances.

Demonstration Experience

PDI has qualified a large number of instrument and search unit combinations. It has been our experience that a properly operating and calibrated system has never been the cause of failure. As a part of each personnel and procedure qualification the following essential variables are recorded:

a. Instrument make and model
b. Essential instrument settings
c. Search unit make and model
d. Search unit angle
e. Cable type, maximum length and maximum number of intermediate connectors.

On conclusion of each successful qualification demonstration the essential variables used are compared to the current list of qualified instrument and search unit combinations (Table 1). If this particular combination is not listed in the current Table 1, we determine if that particular combination was successful in detecting flaws when used in accordance with the procedure. If the combination

was successful (used and useful) in detecting the flaws that were presented it is added to Table 1. The qualified instrument settings are recorded in Table 2. These systems must be calibrated before each use and the qualified settings from Table 2 must be used.

Tables 1 and 2 are updated periodically and the results are published on the EPRIQ Web site. Individuals including vendors', utilities, authorized inspectors and NRC Regional Inspectors may have access to this site for the purpose of assuring the essential variables used during an examination have been qualified according the requirements of Appendix VIII. To obtain access, contact jarendt@epri.com.

Our largest database is from our piping qualification program. PDI has conducted more than 93 piping qualification sessions since 1994. Each session contains from 10 to 15 candidates and is completed over a period of two to three weeks. There have been a total of 5497 piping demonstrations and 2682 of these have been successful. Each candidate must supply his own instrument, cables and search units. If no more than 20% of these were unique i.e., different serial numbers that would indicate on the order of 1,000 instruments have been used. The number of search units used in an examination can be as high as 14. Using the conservative 20% estimate that would indicate on the order 10,000 unique search units. We have not observed that an individual using a functioning instrument has failed the examination as a result a result of a faulty instrument or search unit. Our experience has shown that no one instrument or search unit of a particular make and model performs any better or worse that another of the same make and model.

Table 1 is specific to a procedure and its application. There are a total of 16 instruments included with 722 essential variable combinations listed for the austenitic piping application. A tabulation of essential variable combinations is shown in Figure 1. The three most widely used instruments account for more than half of the qualified instrument and search unit combinations.

Conclusion

The PDI Program has qualified a large number of instruments and search units since 1994. We estimate that more than 1,000 instruments and 10,000 search units have been used in PDI Piping demonstrations. In that period we have not observed an operating and calibrated instrument has resulted in failure of a candidate. We have not observed that one particular instrument performs any better or worse than another of the same make and model.

In summary we accept the standard OEM tolerances and variability that are controlled by the manufacture's quality assurance program. These tolerances appear to be adequate to assure that the exchange of units of the same make

and model will perform sufficiently well to meet the performance based demonstration requirements of Appendix VIII.

We believe that the requirements in the 2002 Addenda are correct and meet the intent of the performance demonstration process. This position is also supported by two other international Performance Demonstration Agencies. An intent inquiry and Code change have been reviewed, approved and published by the ASME Code.

TABLE 1 ENTRIES FOR PDI UT-2 AUSTENITIC PIPING

MODEL	MANUFACTURE	# COMBINATIONS	CUMULATIVE TOTAL
SONIC 136	STAVELEY	225	225
USK 7D	KRAUTKRAMER	101	326
EPOCH II	PANAMETRICS	58	384
USN 50	KRAUTKRAMER	53	437
SONIC 137	STAVELEY	52	489
EPOCH III	PANAMETRICS	49	538
USN 52L	KRAUTKRAMER	40	578
EPOCH IIB	PANAMETRICS	40	618
USN 52R	KRAUTKRAMER	29	647
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USN 60	KRAUTKRAMER	15	682
MASTER 335	SONATEST	11	693
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EPOCH 4	PANAMETRICS	8	710
USN 52	KRAUTKRAMER	6	716
MASTER 330	SONATEST	6	722

Figure 1: Summary of instrument and search combinations qualified for austenitic piping examinations.

References:

1. Guidelines on the Management of NDT-System Essential Variables Subject to the Qualification Requirements of the Swedish Nuclear Power industry, SQC Guideline 1, rev A, October, 2000, SQC Kvalificeringscentrum AB, Taby Sweden, pp20-21, available at www.sqc.se
2. Pressurized Water Reactor Steam Generator Examination Guidelines: 6, EPRI Technical Report 1003138, October 2002, pp j-8 through j-11.
3. ASME Boiler and Pressure Vessel Code, Section XI Div.1, Appendix VIII, 2001 Edition and 2002 Addenda.