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NONDESTRUCTIVE EXAMINATION OF DOE HIGH-LEVEL WASTE STORAGE TANKS

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ABSTRACT

A number of DOE sites have buried tanks containing high-level waste. Tanks of particular interest are double-shell inside concrete cylinders. A program has been developed for the inservice inspection of the primary tank containing high-level waste (HLW), for testing of transfer lines and for the inspection of the concrete containment where possible. Emphasis is placed on the ultrasonic examination of selected areas of the primary tank, coupled with a leak-detection system capable of detecting small leaks through the wall of the primary tank. The NDE program is modelled after ASME Section XI in many respects, particularly with respect to the sampling protocol. Selected testing of concrete is planned to determine if there has been any significant degradation. The most probable failure mechanisms are corrosion-related so that the examination program gives major emphasis to possible locations for corrosion attack.

INTRODUCTION

The Department of Energy is responsible for the high-level wastes stored in underground tanks, primarily at Hanford and Savannah River sites, with some at Idaho National Engineering Laboratory and West Valley. While both single-shelled tanks and double-shelled tanks contain waste, the emphasis in this paper will be on the inspection and testing of the double-shelled tanks. These tanks are expected to be used well beyond their 40-year design life; therefore, a decision was made to examine a sample of the tanks for evidence of degradation. The anticipated degradation mechanisms are one or more forms of corrosion such as uniform-, pitting-, stress- and/or crevice-corrosion that could lead to selective wall thinning or local penetration.

Non-destructive examination techniques applicable to the detection of localized corrosion in an underground tank containing highly radioactive liquids probably are limited to remote visual examination of the surface above the liquid, and of the inner surface of the secondary tank, or volumetric (ultrasonic) examination from the outer surface of the primary tank.

The following is a brief description of the suggested guidelines for both examination and testing of the tanks and for testing the transfer piping. These guidelines use ASME Section XI [ASME, 1989] as a model for the inservice inspection and testing.

SCOPE

The following issues will be discussed:

- Purpose of generic NDE guidelines;
- Approach;
- Bases for flaw sizes;

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- Basis for examination percentages;
- Reasons for selection of UT angles;
- Implications of Section XI Articles cited;
- Exemption mechanism with examples;
- Testing.

EXAMPLES OF PROPOSED HLW TANK EXAMINATIONS

On the assumption that one or more corrosion mechanisms represent the most probable mode of degradation, an examination plan has been developed that covers regions to be examined, examination requirements, methods, "flaw" acceptance levels, extent of examinations, and frequency of examinations. Table 1 presents these criteria and their suggested values.

PURPOSE OF GENERIC NDE GUIDELINES

A significant reason concerns the projected duration of the high-level waste programs (possibly to the year 2050). A viable alternative to constructing new tanks as the design life is reached, is to justify the continued use of existing tanks, through a program such as the NDE guidelines, for an extended period, e.g., 60-70 years total, by confirming that only limited degradation has occurred. An early detection of generic degradation such as severe pitting, wall thinning, stress-corrosion cracking, will minimize the need for "panic" solutions when leakage is detected.

APPROACH

Two options were available in developing the NDE guidelines:

- A complete, stand-alone document, including justification for every position cited;
- A "lean" guideline based on a consensus code such as ASME Section XI;

Stand-Alone Document - Such an approach could have used existing inspection "standards" such as those of the American Petroleum Institute for thin-walled tanks. This approach was discarded for the following reasons:

- The API "standards" are not true consensus standards; therefore, all provisions would require justification;
- While the API standards have a good technical basis, they lack any tie to nuclear applications. This was considered a possible limitation;
- A complete stand-alone guideline would be about 100 pages in length and require much longer to develop.

Consensus Code Approach - We recognize that Section XI was developed for thicker-walled vessels; however, piping examinations with ultrasonics often are on thicknesses less than the waste tanks. The principal differences being in the diameter to thickness ratios. This approach was selected because:

- Section XI is a consensus Code approved for use in commercial nuclear power plants by the USNRC;
- About 25 years' experience and thousands of man-days effort have been expended in the development of Section XI;
- The sampling approach used in Section XI represents the only viable NDE option for the high-level waste tanks because of time/manpower limitations;
- Many articles can be cited by reference without further justification;
- NDE techniques, including both equipment and NDE operator qualification are well defined;
- Section XI relies heavily on feedback from utilities, regulators and other interested parties to continuously modify and upgrade the Code so that real problems can be solved;
- The use of relevant parts of Section XI permits a short guideline document.

The consensus approach was selected because of its relative simplicity and the major saving in time of document preparation. The ability to reference a Code document markedly reduced the level of effort of the Panel. Modelled after Section XI IWB-2500 and recognizing the significant role of corrosion in high-level waste tanks, Table 1 covers what to examine for, where, how, and how often, employing the Code approach of selecting a relatively small sample for examination, with sequential sampling used in the event flaws are detected.

BASES FOR FLAW SIZES

The waste tanks have thicknesses of one-inch or less, are fabricated of carbon steel in most cases, and must be examined with remote UT, VT, or PT. A significant factor is the relatively low loads to which the tanks are exposed. Basically, the major load is hydrostatic with some cyclic thermal and mechanical loads. The Cumulative Usage Factor (CUF) probably is less than 0.1. This limits significant degradation mechanisms to corrosion (pitting, crevice, bulk, and stress-corrosion for example). Because of low loads and thin sections, triaxial stresses are eliminated so that an unstable flaw should be quite long, even under Level D seismic loads. Therefore, the intent of NDE programs is to detect generic failure mechanisms and to provide early warning of such failure mechanisms within the limitations inherent in a sampling program.

In contrast to Section XI where the cutoff for flaw sizes requiring no additional action is 2.5%t, the low loads of the tanks and the biaxial stresses inherent in thin sections permit much larger permissible flaw sizes before there is a need to increase the examination sample size. These reasons are the justification for the values of 20%t and 50%t included in the guidelines and Table 1.

BASIS FOR EXAMINATION PERCENTAGES

The approach was to select regions for examination that were believed to be most susceptible to the anticipated mechanisms of pitting, crevice, bulk, or stress-corrosion.

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The sample size was selected to provide a reasonable confidence of detecting generic degradation. The sample size was a compromise based on complexity of remote automated NDE. The sample represents a lower bound for reliable detection of generic degradation: it is roughly comparable to Section XI IWC values.

REASONS FOR SELECTION OF UT ANGLES

The lack of success in detection and sizing of flaws with single angle UT in the early years of Section XI and the statistically validated results of the Program for the Inspection of Steel Components (PISC II and PISC III) led to the decision to require four angles (0°, 45°, 60°, and 75° L-wave). The 0° choice is obvious for pits and for wall thinning. With stress corrosion the lack of success in the absence of a definite qualification program and the lack of success in detecting intergranular stress corrosion in wall thicknesses of 0.2 to ~1.5-inches was confirmed in the intergranular stress-corrosion cracking (IGSCC) occurring in BWRs and in PISC programs using implanted fatigue and stress-corrosion cracks.

IMPLICATION OF SECTION XI ARTICLES CITED

Several articles/appendices of Section XI are cited; namely, IWA-2240, IWA-2430, IWB-2420, IWB-2430, specific articles in Appendix III and specific articles in Appendix VIII. The examination interval of ten years in IWA-2430 was selected as a reasonable interval. This was divided into two inspection periods of five years rather than the three of Section XI. IWA-2240 permits alternative examinations; however, the burden of proof is on the user to determine the reliability of this alternative procedure. IWB-2420 covers successive examinations from interval to interval. IWB-2430 covers additional examinations when flaws are found that exceed in size permitted by the acceptance standards.

Two appendices are cited; Appendix III is usually used for piping. The procedure in the appendix has been revised to include more examination angles. The three angles required represent a conservative position. If the results from Appendix VIII indicate that a sufficient level of reliability can be obtained with two angles for IGSCC, then the guidelines should be revised. Appendix VIII represents a performance demonstration using samples comparable in thickness to the tank and containing the most probable flaws (pits, thinning, IGSCC). Use of these specimens should qualify the UT equipment and establish the reliability of flaw detection and flaw sizing.

EXEMPTION MECHANISM WITH EXAMPLES

The Section XI Code is made up of a number of requirements. In some instances a utility cannot comply. For example, a terminal end weld may be inaccessible because of lack of access (walls, pipes, supports). Another and relevant instance is the examination of BWR reactor pressure vessels where access predominantly is from the external surface, gaps between vessel and biological shield often are limited so that specialized small remotely controlled crawlers represent the only viable option for UT. Utilities often request repeated exemptions, pending the development and availability of the necessary UT equipment.

An example, more appropriate to the high-level waste tanks is cited below.

<u>Example</u> - Some Westinghouse Savannah River Company waste tanks were not stress-relieved and have experienced through-wall IGSCC. The number of through-wall cracks range from a few in some tanks to a large number in others. There is a high probability that these tanks contain IGSCC that has not penetrated the wall. Certainly, some of the non-stress-relieved tanks should be included in the examination sample; it is quite probable that IGSCC will be detected. The following recommendations are made:

- "New" IGSCC detected should comply with IWB-2420 regarding successive examinations. If three successive examinations confirm no crack growth, further UT is not required per IWB-2420. The lack of flaw growth, if confirmed, will be a valuable validation that inhibitors halt the growth of IGSCC, even after it has initiated.

- "New" IGSCC detected should <u>not</u> invoke IWB-2430 regarding additional examinations. We know that IGSCC has occurred. Invoking IWB-2430 has a high probability of expanding the sample to 100% of accessible welds. This would require an expenditure of time and money out of proportion to the value added information. The purpose of the NDE guidelines program should be to detect <u>new</u> generic degradation, not to trigger more examinations of a known and well documented problem.

TESTING

Testing has two purposes; namely, to determine if leakage is occurring in the HLW primary tank or if the transfer piping primary pipe is leaking, and to determine if there has been excessive degradation in components such as the concrete base mat, cylinder, or dome enclosing the double-shelled tanks. For example, leakage is detected by monitoring the gas flow through the annulus between the inner and outer tanks, measuring either moisture content, radioactivity level or both. Transfer pipes undergo a pressure test prior to any HLW transfer. Concrete properties can be determined by removal and testing of core samples if such is deemed necessary. Samples have been removed from various concrete structures to determine if degradation has occurred. At present an analytical program is used that can be expanded to coring and testing if the analyses indicate degradation.

SUMMARY

The preceding discussion is a brief overview of an ongoing program whose ultimate aim is to monitor the high-level waste tanks at the various DOE sites for any indication of degradation. The current status is limited to a completed document with recommendations that could be used by the various sites in planning their inservice examination and testing programs. The DOE sites are reviewing the document as a basis for developing an ISI specification.

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REFERENCES

ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," ASME, New York, 1989, with Annual Addenda.

TABLE 1 - EXAMINATIONS OF CARBON OR LOW-ALLOY AND AUSTENITIC STAINLESS STEEL OR HIGH-ALLOY TANK CONTAINING HIGH-LEVEL WASTE

REGION EXAMINED	EXAMINATION REQUIREMENTS	EXAMINATION METHODS	ACCEPTANCE LEVELS	EXTENT OF EXAMINATION	FREQUENCY OF EXAMINATION
LIQUID-VAPOR INTERFACE	± ONE FOOT OF INTERFACE	VOLUMETRIC (0° UT)	PITS, <50%t	5% OF INTERFACE LENGTH OF EACH TANK TO BE EXAMINED*	EACH INSPECTION INTERVAL (DIVIDED INTO TWO PERIODS)
LIQUID-SLUDGE INTERFACE, IF SUCH EXISTS	± ONE FOOT OF INTERFACE	VOLUMETRIC (UT) FROM OUTER SURFACE	PITS(<50%), CRACKS(<50%), GROSS CORROSION	5% OF INTERFACE LENGTH OF EACH TANK TO BE EXAMINED	EACH INSPECTION INTERVAL
LOWER KNUCKLE OF PRIMARY TANK	UPPER WELD	VOLUMETRIC	CRACKS <20%	5% OF LENGTH DIVIDED INTO TWO OR MORE SEGMENTS IF ACCESSIBLE	EACH INSPECTION INTERVAL
LOWER KNUCKLE OF PRIMARY TANK	PREDICTED MAXIMUM STRESS REGION OF BASE METAL PLUS LOWER WELD IF ACCESSIBLE	VOLUMETRIC	CRACKS <20%	5% DIVIDED BETWEEN KNUCKLE BASE METAL AND LOWER WELD IF ACCESSIBLE OTHERWISE 5% OF KNUCKLE DIVIDED INTO TWO OR MORE SEGMENTS	EACH INSPECTION INTERVAL
EXTERNAL SURFACE OF PRIMARY TANK IF ACCESSIBLE, AND INTERNAL SURFACE OF SECONDARY TANK IF SUCH EXISTS	OVERALL SCAN OF ACCESSIBLE REGIONS	REMOTE VISUAL	ANY SIGNS OF DEGRADATION MUST BE EVALUATED	ALL ACCESSIBLE REGIONS	AT LEAST ONCE EACH INSPECTION INTERVAL
EXTERNAL SURFACE OF PRIMARY TANK IF ACCESSIBLE	BELOW NOMINAL VAPOR-LIQUID INTERFACE	VOLUMETRIC (0°) UT	WALL THINNING <20%	5 - 1 FT^2 AREAS PER TANK	EACH INSPECTION INTERVAL

TABLE 1 - EXAMINATIONS OF CARBON OR LOW-ALLOY AND AUSTENITIC STAINLESS STEEL OR HIGH-ALLOY TANK CONTAINING HIGH-LEVEL WASTE (Continued)

REGION EXAMINED	EXAMINATION REQUIREMENTS	EXAMINATION METHODS	ACCEPTANCE LEVELS	EXTENT OF EXAMINATION	FREQUENCY OF EXAMINATION
VAPOR REGION AT TOP OF PRIMARY TANK	CONFIRM VT WITH PT OR UT IF ATTACK IS FOUND	REMOTE VISUAL	EVIDENCE OF ATTACK SHOULD BE EVALUATED	REMOTE SCAN OF VAPOR REGION	EACH INSPECTION INTERVAL
PLATE MAKING UP BOTTOM OF TANK IF ACCESSIBLE	"BEST EFFORT" NDE EXAMINATION	VOLUMETRIC	CRACKING(<50%), THINNING(<20%), PITTING(<50%)	PRIMARILY FOR NEW TANKS DESIGNED FOR ACCESSIBILITY; HOWEVER, LIMITED SCANS SHOULD BE CONDUCTED IF FEASIBLE	EACH INSPECTION INTERVAL
OVERALL SCAN OF INTERNAL SURFACE	WHEN A TANK IS ESSENTIALLY EMPTY	REMOTE VISUAL	EVIDENCE OF DEGRADATION SHOULD BE EVALUATED	GENERAL SCAN OF INSIDE OF PRIMARY TANK	WHEN A TANK IS EMPTY

• TANK POPULATION TO BE EXAMINED IS 10% OF TANKS, BUT NOT LESS THAN ONE; ALTERNATIVELY, THE POPULATION EXAMINED MAY BE GREATER THAN 10% WITH A COMPARABLE REDUCTION IN THE AMOUNT EXAMINED IN EACH TANK, PROVIDED THE TOTALS ARE THE SAME AS FOR THE 10% POPULATION.

THE INSPECTION INTERVAL IS 10 YEARS; THE INSPECTION PERIOD IS APPROXIMATELY 5 YEARS.