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Recommendations for Erosion-Corrosion Allowance for Multi-Function Waste Tank Facility Tanks

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
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RECOMMENDATIONS FOR EROSION-CORROSION ALLOWANCE FOR MULTI-FUNCTION WASTE TANK FACILITY TANKS

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ABSTRACT

The Multi-Function Waste Tank Facility carbon steel tanks will contain mixer pumps that circulate the waste. On the basis of flow characteristics of the system and data from the literature, an erosion allowance of 0.075 mm/y (3 mil/year) was recommended for the tank bottoms, in addition to the 0.025 mm/y (1 mil/year) general corrosion allowance.

Keywords: corrosion, erosion, carbon steel, MWTF, double-shell tank, DST, pump, corrosion allowance.

INTRODUCTION

The U.S. Department of Energy (DOE) Hanford Site near Richland, Washington is planning the construction of six 1.1-million gallon (4163 m^3) carbon steel high-level radioactive waste double-shell storage tanks (DSTs), called the Multi-Function Waste Tank Facility (MWTF) project(1).

BACKGROUND

The waste will be continuously mixed with a mixing pump. The requirements for the mixing system were based on what was deemed necessary for effective waste transfer and storage. The mixing requires two 150-hp (112-kw) pumps to be installed and 90% homogeneity in waste density established(2)(3). Planned operation is to operate one of these pumps at a time. Also, as the pumps are variable speed pumps, the majority of operation will most likely be less than at maximum speed. Figure 1 shows the jet pump flow pattern in the tank.

SA 516 carbon steel has been selected as the material of construction for the MWTF tanks. Carbon steel tanks have been used successfully for many years to store high-level radioactive wastes both at Hanford and at other U.S. Department of Energy (DOE) sites. Compatibility of the nitrate wastes with carbon steel is assured by inhibiting the wastes with sodium hydroxide to a pH above 12. Above a pH of 10, a passive film forms on the surfaces of exposed carbon steel, prevents stress corrosion cracking, and controls the corrosion rates to values below 1.0 mil/year (0.025 mm/y)(4)(5). This passive film, which is a corrosion product layer, is responsible for the low corrosion rates of carbon steel observed in double-shell tank (DST) waste. Disturbing or removing this layer results in substantial increases in the corrosion rates of the carbon steel surfaces. This passive layer tenaciously adheres to the carbon steel surface.

The mixing pumps in the MWTF tanks will produce flows, currents, and/or eddies on the bottom of the tank that will probably remove the passive layer or will increase the rate of transport of chemical species to or away from the metal surface and increase the corrosion rate(6). Removal of the passive layer or increasing specie transport by the action of the flowing waste is called erosion-corrosion. Because removal of the passive layer by the mixing pumps cannot be prevented, an erosion-corrosion allowance will be considered to be added to the ASME design requirements for minimum wall thickness of the tank. This erosion allowance is in addition to the 1 mil/year (0.025 mm/y) general corrosion allowance added to the design requirements for minimum tank wall thickness.

EVALUATION

A review of Corrosion Abstracts, the on-line databases at the Pacific Northwest Laboratory (PNL) library, and various DOE reports was performed. The abstracts provided no hard data. The on-line search similarly did not provide significant additional information. The DOE reports noted were more informative.

A brief summary of the abstracted and on-line information is:

> As anticipated, the erosion rates are a function of the hardness and roughness of the abrasive, its particle size, velocity, corrosiveness of the solution, and the type of inhibitors(7). It also has been noted however, that there appears to be critical velocity above which inhibitors lose their effectiveness(8). Though the actual value of the critical velocity is not known, it is estimated to be about 65 fps (20 m/s), which is approximately the maximum tested in Smith and Elmore's work(9).
>
> Coatings are also effective (10)(11). The presence of additional silicon may also be useful in some alloy compositions (12). Davis, in his lecture notes(13), points out that having as little as 0.2% chromium (Cr) in a mild steel reduces the wear rate by about 80%. (Note that A-537 carbon steel can have a maximum of 0.25% Cr [heat analysis or 0.29% by product analysis] whereas A-516 has no specified amount. If ASTM A 20 is applied, then the Cr content of A-516 can be specified at a maximum of 0.30%, heat analysis, or 0.34%, product analysis.) He also notes that the erosion rate is nearly directly proportional to the fluid flow rate.
>
> In liquid systems it has been found that the maximum erosion occurs at impact angles of 40° and 90°(14).

Blackburn[15] suggested the maximum erosion rate in the Hanford grout system should be considered to be about 20 to 40 mil/year (0.5 to 1.0 mm/y) rather than the 1 to 4 mil/year (0.1 mm/y) observed by Smith & Elmore in their study[9]. The rationale for the higher rates is that the grout is more abrasive than the NCAW and the NCRW slurries Smith & Elmore studied. They noted that erosion-corrosion rates of 3 to 4 mil/year (0.075 to 0.1 mm/y) were observed at jet velocities of about 15 fps (4.6 m/s).

Zapp at the Savannah River Site (SRS)[16] notes that erosion-corrosion rates as high as about 800 mil/year (0.8 in./y or 20 mm/y) have been observed in uninhibited coal and sand slurries. The addition of inhibitors reduced these rates to approximately 20 mil/year (0.5 mm/y). He also references work that states sand slurries have a critical velocity of 3 to 8 fps (0.1 to 2.4 m/s) above which erosion increases. Zapp concluded that for SRS purposes, even Smith & Elmore's data were high and that SRS could expect erosion-corrosion rates of less than 1 mil/year (0.025 mm/y).

Roco and Cader[17], after reviewing slurry pipeline data and performing laboratory testing and modeling, reported on the effects of velocity (V), particle size (d_p), and particle concentration (C_p). They note that the erosion rate varies:

In proportion to V^n where $n = 0.73$ to <1.70; the value of n cannot be easily predicted because it is a function of the flow pattern and the various wear mechanisms,

In proportion to d_p^m where $m \approx 0.875$, and

Linearly with C_p in the range of 5 to 35% solids.

They also noted that in phosphate slurry pipelines with a velocity of about 5.2 m/s (17 fps) an average particle size of 0.5 mm, and a concentration of 13%, the erosion rate was about 1.32 µm/h (455 mil/year [11.8 mm/y]). There was no discussion about the effect of inhibitors.

In discussions with T. R. Beaver[3], it was determined that the present plans for the pumps provide for nozzle velocities of up to 100 fps (30.5 m/s). At closest approach of about 25 ft (7.6 m) (the pump will be offset 13 ft (4 m) from the center), the impingement flow rate is estimated at approximately 2 to 4 fps (0.6 to 1.2 m/s) at a maximum, a value that is negligible compared to the maximum in Smith & Elmore's work. However, at a distance of about 4 ft (1.2 m) from the nozzle[3], the jet stream is expected to intercept the bottom of the tank. At those distances, a maximum velocity of about 25 fps (7.6 m/s) adjacent to the bottom could be expected. This will be "parallel" to the bottom though and not direct impingement as in Smith & Elmore's work. However, at the location where the jet actually attaches itself to the bottom, there may be fluctuations that approximate direct impingement.

Waters(18) confirmed that the velocities used by Smith & Elmore still encompass the expected velocity profile in the proposed MWTF. Further, Waters alleviated a concern that sand could be a problem if it was present in the bottom of the tanks. He said that if sand is present, and it is likely to be, it will be blown away from the region of the pump and nozzles and not be entrained by the flow. Hence, except for a possible short period at start-up, the slurry should consist only of waste that, as shown by Smith & Elmore, is not highly abrasive.

CONCLUSIONS

Based on the evaluation of the literature, laboratory testing, and past experience the MWTF tanks require a corrosion-erosion allowance on the tank bottom to maintain the required ASME minimum wall thickness during its 50 year design service life.

RECOMMENDATIONS

The following recommendations are presented to address the erosion-corrosion concerns in the MWTF tanks.

- Inside the MWTF tanks on the bottom, a 3 mil/year (0.075 mm/y) erosion-corrosion allowance should be added to the 1 mil/year (0.025 mm/y) general corrosion allowance which is added to the minimum wall thickness calculations from the design. Thus a 4 mil/year (0.1 mm/y [0.2 in. or 9 mm]) total thickness for the 50-year design life) is required to be added on the bottom of the tank to the minimum wall thickness resulting from the analysis performed to the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Division 1, NC-3900(19).

  OR

  Inside the MWTF tank, on the bottom over a radius of 15 ft (4.6 m) centered under each mixer pump, 3 mil/year (0.075 mm/y [0.15 in. or 6.8 mm]) total thickness for the 50-year design life) of carbon steel erosion-corrosion allowance should be added to that required by the ASME design calculations for minimum wall thickness and general corrosion allowance.

- No erosion-corrosion allowances are required for the MWTF tank walls.

- A supplemental purchase requirement to specify chromium levels between 0.20% and the maximum allowed by the ASME SA 516 specification is recommended in order to obtain maximum erosion-corrosion resistance.

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Figure 1. MWTF Tank Flow Pattern Jet Velocity

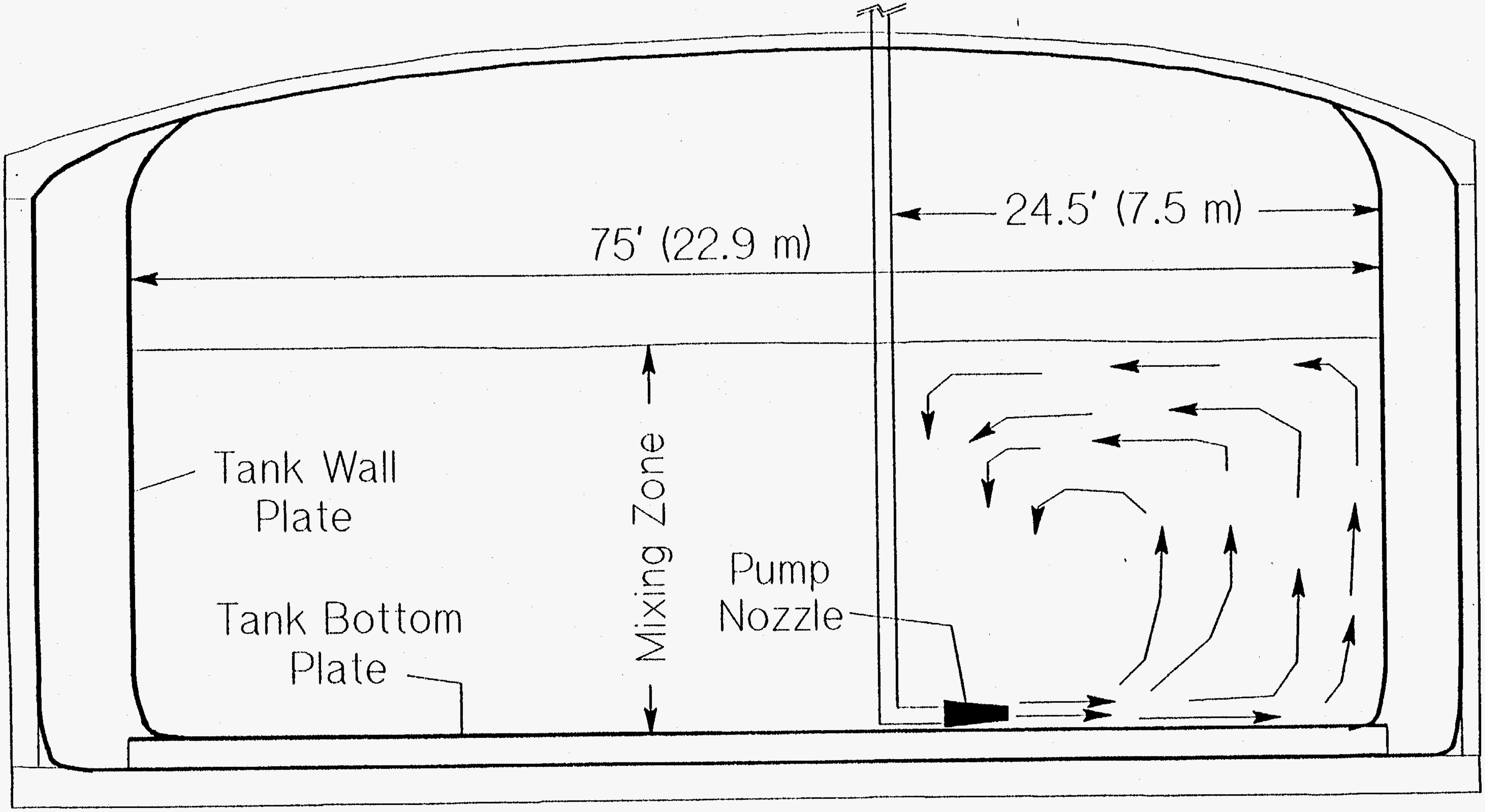
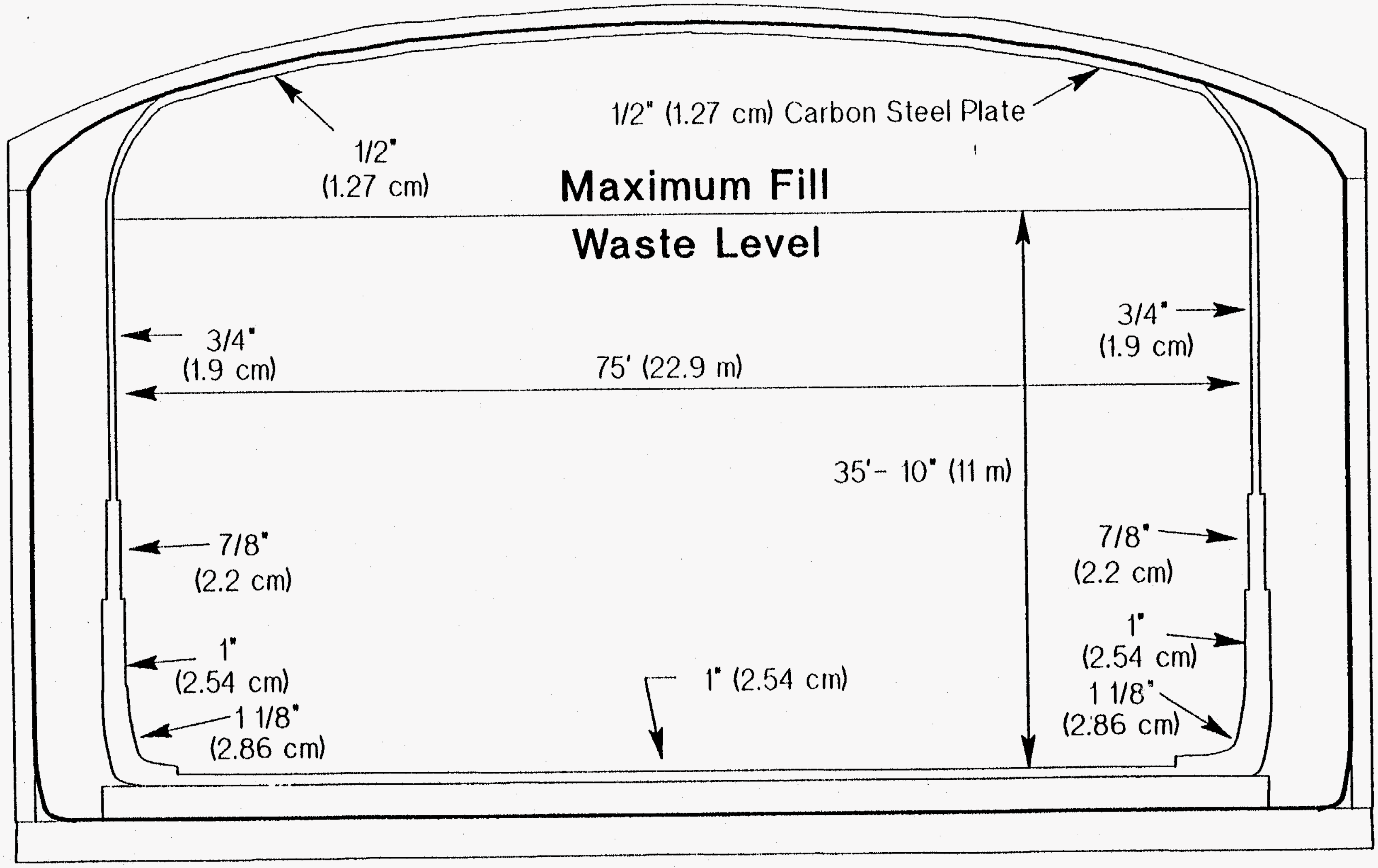


Figure 2. MWTF Tank Plate Sizes



Wall thicknesses include:

0.050 inch (0.13 cm) (0.001inch/year (0.025 mm/yr)) general corrosion allowance around entire tank interior.

0.150 inch (0.38 cm) (0.003 inch/year(0.075 mm/yr)) erosion -- corrosion allowance on tank bottom.

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