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Justification for a Limit of 15% Hydrogen in a 55-Gallon Drum

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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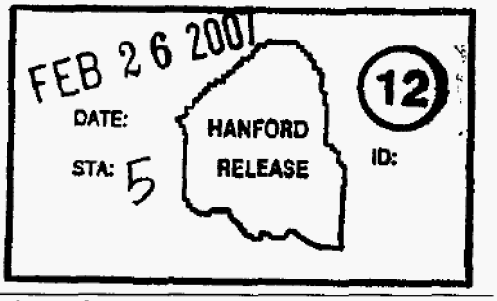

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The concentration of 15% hydrogen in air in a waste drum is used as the concentration at which the drum remains intact in the case of a deflagration.

The following describes what could happen to the drum if 15% hydrogen or more in air were ignited.

Table 2 of the Savannah River report WSRC-TR-90-165 *TRU Drum Hydrogen Explosion Tests* provides the results of tests performed in 55-gallon drums filled with hydrogen and air mixtures. The hydrogen-air mixtures were ignited by a hot-wire igniter. The results of the tests are shown in Table 1 below.

Table 1. Drum Pressures and Effects due to Ignition of Hydrogen and Air Mixtures in 55-Gallon Drums

Hydrogen Concentration, %	Peak Pressure, psig	Observation
13.346	70.4	Bulged
13.945	69.1	Bulged
14.053	138	Bulged
14.893	69	Bulged
16.49	121.4	Bulged
16.95	137.5	Lid Blown
17.966	211.1	Lid Blown

They concluded that drums can withstand deflagration involving hydrogen concentration up to 15% hydrogen.

Testing was performed at Idaho Falls and documented in a letter from RH Beers, Waste Technology Programs Division, EG&G Idaho, to CP Gertz, Radioactive Waste Technology Branch, DOE dated Sept. 29, 1983. In these tests, 55-gallon drums were filled with hydrogen-air mixtures which were ignited. The results in Table 2.2 showed that ignition for drums containing 11% and 14% hydrogen, the drum lid remained on the drum. Ignition in drum with 30% hydrogen resulted in lid loss.

It is concluded from the results of these two tests that, for uncorroded drums, a 15% hydrogen in air mixture will not result in loss of drum integrity (i.e., lid remains on, walls remain intact).

The drum walls however, may be thinned due to corrosion. The effect of the deflagration on thinner walls is assessed next. Assume a 15% hydrogen in air mixture exists in a drum. The pressure assuming adiabatic isochoric complete combustion (AICC) conditions is 69 psig (using the same deflagration pressure calculation method as in HNF-19492, *Revised Hydrogen Deflagration Analysis* which got 82 psig for 20% hydrogen in air).

Roark's Formulas for Stress and Strain, Table 13.1, Case 1b shows the stress in a thin-walled pressure vessel due to internal pressure. The stress is given by:

$$\sigma = \frac{qR}{t}$$

where q = internal pressure, psig
= 69 psig for a 15% hydrogen in air mixture that is ignited
R = radius of the drum, in.
= 12 in.
t = thickness of the drum walls, in.
= 0.0598 in. for DOT-17C drums (16 gauge) per HNF-2209, *Safety Analysis Report for Packaging (Onsite) Steel Drums*, Table A2.1.
= 0.0478 in. for DOT-17H drums (18 gauge) per HNF-2209, Table A2.1
σ = stress

Solving for "σ" yields

13,850 psi for DOT-17C drums
17,300 psi for DOT-17H drums.

The ultimate stress for these drums is given as 58,000 psi in Table B7-1 of HNF-2209. The ultimate stress is used as drum failure is the concern.

If the internal pressure were 138 psig (largest pressure from Table 1 for hydrogen concentrations at or below 15%), the stress would be 27,700 psi for the DOT-17C drums and 34,700 psi for the DOT-17H drums.

The walls would have to thin to

DOT-17C; 0.0286 in. (or 48% of the original thickness)
DOT-17H; 0.0286 in. (or 60% of the original thickness)

for the stress from a pressure of 138 psig to equal the ultimate stress. An even greater thinning of the walls would have to occur for the stress to exceed the ultimate stress under AICC conditions (i.e., about 69 psig) which essentially occurred in the other three tests (shown in Table 1) at hydrogen concentrations below 16%.

From the above, it is seen that, the drums walls can withstand the stress even if the walls had thinned to about half of the nominal thickness. The MDSA states that drums must be vented and abated until the hydrogen level is <15% before movement or further processing can occur. The abatement period is based on the hydrogen content determined at venting and correlated to the performance characteristics of the installed vent. The MDSA states "In addition, in the period immediately after venting, oxygen will diffuse into the drum as flammable gases diffuse out, creating conditions favorable for ignition until the flammable gas decreases to a level below 15% hydrogen. Based on previous diffusion sampling of vented drums, several days of staging will be required to reduce the flammable gas concentrations (HNF-16166)." (HNF-14741,

Section 3.4.2.1.1) In normal operations the drums are not moved until the estimated hydrogen level is <5%, however the drums may be moved for operational efficiencies within the LLBG once the level is <15%.

References

Beers, R.H., 1983, *Gas Generation: Year-End Report, FY-1983*, (external letter, RHB-387-83, to C.P. Gertz, Idaho Operations Office, DOE, Sept. 29), EG&G Idaho, Inc., Idaho Falls, Idaho.

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Roark's Formulas for Stress and Strain, Seventh Edition, 2002, McGraw-Hill, New York, New York.

WSRC-TR-90-165, 1990, *TRU Drum Hydrogen Explosion Tests*, Westinghouse Savannah River Company, Aiken, South Carolina.

Desk Instruction 2.0, Rev. 1

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed - HNF-32836 Rev 0 _____

Title: *Justification for a Limit of 15% Hydrogen in a 55-Gallon Drum,* February, 2007, by Robert Marusich
Scope: whole document

Yes	No*	NA		
[X]	[ ]	[ ]		Referenced analyses appropriate.
[X]	[ ]	[ ]		Problem completely defined and all potential configurations considered.
[X]	[ ]	[ ]		Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]		Necessary assumptions explicitly stated and supported.
[ ]	[ ]	[X]		Computer codes and data files documented.
[X]	[ ]	[ ]		Data used in calculations explicitly stated in document.
[X]	[ ]	[ ]		Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]		Mathematical derivations checked including dimensional consistency of results
[X]	[ ]	[ ]		Models appropriate and used within range of validity, or use outside range of established validity justified.
[X]	[ ]	[ ]		Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
[ ]	[ ]	[X]		Software input correct and consistent with document reviewed.
[ ]	[ ]	[X]		Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]		Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[X]	[ ]	[ ]		Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]		Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]		Results and conclusions address all points required in the problem statement.
[X]	[ ]	[ ]		Format consistent with applicable guides or other standards.
[ ]	[ ]	[X]	**	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]		Document approved (for example, the reviewer affirms the technical accuracy of the document).

Paul D. Rittmann Paul Rittmann 2-20-07
Technical Peer Reviewer (printed name and signature) Date

* All "no" responses must be explained below or on an additional sheet.

** Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. The material should be labeled and recorded in such a manner as to be understandable to a technically qualified third party.