ENGINEERING DATA TRANSMITTAL

Page 1 of 1

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		QA							
		Safety							
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1	1	Peer Rev. J.C. Van Keuren	<i>[Signature]</i>	7/30/94	A3-34				
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Consequence Analysis of a Postulated NaOH Release from the 2727-W Sodium Storage Facility

D.A. Himes

Westinghouse Hanford Company, Richland, WA 99352
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Abstract: Toxicological and radiological consequences were calculated for a maximum sodium fire in the 2727-W Sodium Storage Facility. The sodium is solid and cannot leak out of the tanks. The maximum fire therefore corresponded to the maximum cross-sectional area of one tank. It was shown that release of the entire facility inventory of ^{22}Na is insufficient to produce an appreciable effect.

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CONSEQUENCE ANALYSIS OF A POSTULATED NaOH RELEASE FROM THE 2727-W SODIUM STORAGE FACILITY

D.A. Himes
6/21/96

The 2727-W Facility houses five stainless steel tanks of solidified sodium in a metal building about 80 m north of the 16th st. rail crossing in the 200 W Area. The tanks are 12 ft (3.7 m) in diameter by 21 ft (6.4 m) long, and are mounted horizontally in the 28 ft (8.5 m) by 84 ft (26 m) building. The tanks are very substantial with an insulating layer of refractory brick approximately 1 ft thick covered by aluminum sheathing. The sodium is slightly contaminated with ^{22}Na with a half life of 2.58 y. The present total facility inventory of ^{22}Na is estimated to be 0.005 Ci. The Preliminary Hazard Analysis for the 2727-W Sodium Storage Facility identified several possible scenarios for release of NaOH. It has been judged that the most credible scenario is a partial building collapse and tank damage due to high wind with accompanying rain leading to a sodium-water reaction and a sodium fire in the damaged tank. The building is rated for a 20 psi wind loading (corresponding to a wind speed of about 90 mph). Based on the annual probability of exceedance for a 90 mph wind at Hanford ($2 \times 10^{-5}/\text{y}$), an annual accident frequency range of "extremely unlikely" (10^{-4} to $10^{-6}/\text{y}$) was assigned.

The approach taken here is to postulate a sodium pool fire with an area corresponding to the maximum cross-sectional area of one tank. Since the sodium is solid and cannot leak out of the tank, this will maximize the sodium release rate and will bound all of the accidents listed in the Preliminary Hazard Analysis. Only the maximum rate of release of NaOH is of interest here since it will be shown that the entire facility inventory of ^{22}Na is insufficient to produce an appreciable effect.

Description of postulated release:

The postulated maximum release rate corresponds to a sodium pool fire with a size equal to the internal tank dimensions, i.e., 12 ft diameter by 20 ft effective length. The assumed area of the fire is then 240 ft^2 (22.3 m^2). No credit was taken for any fire suppression effects by the remains of the top half of the tank or presence of any N_2 cover gas. The standard open pool sodium burn rate of $8 \text{ lb/ft}^2\text{hr}$ ($10.8 \text{ g/m}^2\text{s}$) with an aerosol release fraction of 35% were assumed. Actual data on open sodium fires (Johnson 1979) indicates that about 90% of the sodium combustion product is Na_2O with about 9% Na_2CO_3 and less than 1% NaOH. Because of the ability of Na_2O to react with water to form NaOH, however, all of the sodium released from the fire is normally assumed to come off as NaOH with 1 g of sodium producing 1.74 g of

NaOH. The maximum NaOH release rate is then just $(22.3 \text{ m}^2)(10.8 \text{ g/m}^2\text{s})(0.35)(1.74) = 147 \text{ g/s}$.

TRANSPORT ASSUMPTIONS:

Although a fire normally implies some degree of thermal lofting which would reduce ground level air concentrations (especially near the fire), the intensity of the fire, and therefore the degree of lofting, cannot be predicted. For this reason, fires are normally assumed to be ground level sources for purposes of estimating direct receptor exposures. For a ground level release the onsite receptor is normally assumed to be at a distance of 100 m in the worst direction (WHC 1988). The site boundary receptor for purposes of this analysis is located at the site boundary or the near bank of the Columbia River, whichever is closer, in the worst direction. No receptor evacuation was assumed.

Acute 99.5 percentile ground level release dispersion factors (X/Q) have been generated using the GXQ code (Hey 1994) at each of the 16 sectors at 100 m and at the site boundary or the near bank of the Columbia River. Since toxicological exposures, and therefore maximum air concentrations, are normally the primary concern for a sodium fire, no plume meander was assumed. The resulting X/Qs are reported in WHC-SD-WM-SARR-016 (Savino 1996) as $3.41\text{E}-2 \text{ s/m}^3$ onsite (100 m E) and $2.83\text{E}-5 \text{ s/m}^3$ at the site boundary (8.76 km N).

Radiological hazard:

The sodium stored in the 2727-W Facility is slightly contaminated with ^{22}Na with a half-life of 2.58 y. The total facility inventory at the present time is estimated in the Preliminary Hazard Analysis to be about 0.005 Ci. The dose due to a release Q of ^{22}Na can easily be calculated using the standard formula $\text{Dose} = Q \times (X/Q) \times (\text{BR}) \times (\text{DCF})$ where BR is the light activity breathing rate ($3.3\text{E}-4 \text{ m}^3/\text{s}$) and DCF is the dose conversion factor (rem per Ci inhaled). The dose conversion factor for ^{22}Na is $2.07\text{E}-9 \text{ Sv/Bq}$ ($7.66\text{E}+3 \text{ rem/Ci}$) (EPA 1988). The release of the entire facility inventory of ^{22}Na would therefore produce an inhalation dose of only $4.31\text{E}-4 \text{ rem}$ in the onsite receptor at 100 m E and $3.58\text{E}-7 \text{ rem}$ in the site boundary receptor at 8.76 km N on the near bank of the Columbia River. Both doses are negligible even for a non-mechanistic release of the entire building inventory.

Toxicological exposures:

By the definition of the X/Q, the maximum air concentration of NaOH at a receptor location is just the product of the maximum release rate and the receptor X/Q. A maximum release rate of 147 g/s therefore would produce a concentration of $5.01\text{E}+3 \text{ mg/m}^3$ at the onsite receptor 100 m from the release

point. The largest particulate concentration which can ordinarily be supported in the air at a point away from the source, however, is about 100 mg/m^3 . This corresponds to a very heavy dust condition. Actual data from open sodium fires (Johnson 1979) indicates that, due to rapid agglomeration and fallout of the combustion particles in the first 50 to 100 m, the air concentration at 100 m downwind is actually much lower (see attachment 2). Even so, for conservatism, 100 mg/m^3 is normally assumed at a distance at least 100 m downwind of a heavy particulate source (WHC 1996). The corresponding concentration at the site boundary can be calculated by using the ratio of the X/Qs at the onsite and site boundary receptors. The maximum concentration at the site boundary is then $(100 \text{ mg/m}^3) \times (2.83\text{E-}5 \text{ s/m}^3)/(3.41\text{E-}2 \text{ s/m}^3) = 0.083 \text{ mg/m}^3$.

Conclusion:

As previously demonstrated, the radiological effects of the ^{22}Na contamination in the sodium are negligible even if the entire facility inventory is released. (Any actual release would be much less.) The only effect of concern due to the maximum fire described here would be the toxicological exposure to the onsite receptor at 100 m downwind. For this receptor, the maximum air concentration was very conservatively estimated at 100 mg/m^3 based on maximum air loading. For an accident frequency in the extremely unlikely range (10^{-4} to 10^{-6} /y) the onsite toxic limit is the ERPG-3 (WHC 1988). NaOH is classed as a corrosive/irritant with an ERPG-3 of 100 mg/m^3 (Van Keuren 1995). It should be noted that a sodium fire makes a highly visible white plume, and that onsite personnel 100 m from a sodium storage facility would be expected to stay out of such a smoke plume coming from the facility and to evacuate upwind immediately. The worst-case site boundary receptor would be exposed to an estimated maximum NaOH concentration of 0.083 mg/m^3 . The corresponding limit for this receptor is the ERPG-2 (WHC 1988) which for NaOH is 40 mg/m^3 (Van Keuren 1995).

References:

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WHC-SD-WM-CN-045 Rev 0

Attachment 2
Estimation of NaOH Air Concentration at 100 m

Estimation of NaOH Air Concentration at 100 m Based on Actual Test Data

Five sodium combustion product release tests were conducted in the open atmosphere at the Idaho National Engineering Laboratory (INEL) (Johnson 1979). The purpose of the tests was to determine fallout distributions and characteristics (chemical and physical) of the combustion products. Four of the tests involved forcing hot sodium through jet and spray nozzles where it burned on contact with the air. The fifth test (test no. 4) involved a pool fire, but the fallout data were not tabulated. Tests no. 1 and 2 were chosen for comparison because the release was from moderate heights (5 and 6 m, respectively), and because these two tests covered nearly the full range of the spread in downwind ground contamination data (see Figure 4 in the Reference). The ground contamination results from the pool fire (test no. 4) are included in the same figure and closely match the results from test no. 1. The releases in tests no. 3 and 5 were elevated (30 m) and were in the form of jets which tended to produce larger Na particle sizes. Tests 3 and 5 were therefore judged to be less representative of a ground level pool fire.

It was noted during these tests that there was a rapid initial fallout of the sodium combustion product particles leading to heavy deposition for about the first 50 m downwind of the fire. Beyond the first 50 to 100 m the fallout assumed the typical exponential decrease with distance (i.e., linear on a log-log plot) as expected. In addition, the particle size distribution was measured as a function of downwind distance for test no. 4 (the pool fire). The results show the expected decrease in particle sizes as one moves away from the source. At 100 m the median particle diameter was $35 \mu\text{m}$ with a geometric deviation of 1.67 while at 200 m the median diameter dropped to $20 \mu\text{m}$ with a σ_g of 1.98.

The conditions of tests no. 1 and 2 are shown in table 1. Note that these were both spray releases with the wind speeds measured at the release heights. It was observed that very heavy fallout occurred within the first 50 to 100 m downwind even for the higher wind speeds (and therefore less fallout time).

Table 1: Conditions for sodium fire tests No. 1 and 2

Test No.	Sodium Released (kg)	Release Height (m)	Release Time (s)	Wind Speed (m/s)	Stability Category
1	22.1	5	235	4.0	D
2	25.1	6	315	4.2	A

The 35 μm median particle size at 100 m implies a gravitational settling velocity given by Stokes equation in the form

$$v_g = \frac{2r^2 g \rho}{9\mu}$$

where r is the particle radius ($1.75\text{E-}5$ m), g is the gravitational acceleration (9.8 m/s²), ρ is the density of the particle ($2.27\text{E}+6$ g/m³ for Na₂O), and μ is the viscosity of air (0.018 g/m·s). The resulting value for the settling velocity of the median particle is 8.4 cm/s. Knowing the release time from Table 1 above, the average air concentration at a point 100 m downwind of the source can then be deduced from the fact that the final ground deposition (g/m²) is equal to the average air concentration times the settling velocity times the plume passage time (approximately equal to the release time). Average measured sodium ground contamination levels at 100 m were reported as $1.9\text{E-}2$ g/m² and $1.6\text{E-}2$ g/m² for test 1 and test 2, respectively. The corresponding derived air concentrations are 0.96 mg/m³ Na (1.7 mg/m³ NaOH) and 0.60 mg/m³ Na (1.1 mg/m³ NaOH). Note that the effective NaOH release rates for these two tests were 164 g/s and 139 g/s which are nearly identical to the release rate of 147 g/s assumed for the fire described in the main document. (The usual 35% aerosol release fraction was not applied here since these were elevated spray fires.)

The relatively high wind speeds and neutral to unstable atmospheric conditions present during these tests would tend to increase the dispersion (i.e., decrease the X/Q) and are far from worst-case. The increased turbulence and decreased transport time accompanying such conditions, however, would also produce a competing decrease in the fallout rate at 100 m. Note that the difference in conditions between tests 1 and 2 would produce a decrease in X/Q by about a factor of 8 due primarily to the differences in the dispersion coefficients σ_y and σ_z between Pasquill D and Pasquill A stability. Yet the final ground contamination level per unit release for test 2 is only 30% less than that for case 1.

The two inferred average air concentrations shown above are expected to be somewhat less than the maximum air concentrations because (1) samples were taken in a 90° arc (to include plume meander) and averaged, whereas the sodium fire plume was observed to cover only about a 30° arc. Even allowing a factor of 10 for this effect, however, would still indicate air concentrations far less than the 100 mg/m³ maximum air loading usually assumed for conservatism.

CHECKLIST FOR PEER REVIEW

Document Reviewed: **CONSEQUENCE ANALYSIS OF A POSTULATED NaOH RELEASE FROM THE 2727-W SODIUM STORAGE FACILITY, D.A. Himes, 6/21/96**

Scope of Review: entire document

Yes	No	NA	
☒	☐	☐	* Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☒	☐	☐	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☐	☐	☒	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☐	☐	☒	Software input correct and consistent with document reviewed.
☐	☐	☒	Software output consistent with input and with results reported in document reviewed.
☒	☐	☐	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☐	☐	☒	Format consistent with appropriate NRC Regulatory Guide or other standards
☐	☒	*	Review calculations, comments, and/or notes are attached.
☒	☐	☐	Document approved.

J. C. Van Keuren J. C. Van Keuren
Reviewer (Printed Name and Signature)

7/26/96
Date

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

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document reviewed (include title or description of calculation, document number, author, and date, as applicable):

CONSEQUENCE ANALYSIS OF A POSTULATED NaOH RELEASE FROM THE 2727-W SODIUM STORAGE FACILITY, D.A. Himes, 6/21/96

Submitted by: D.A. Himes

Date Submitted:

Scope of Review: entire document

YES NO* N/A

☒	☐	☐	1. A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
☒	☐	☐	2. Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
☐	☐	☒	3. HEDOP-approved code(s) were used.
☐	☐	☒	4. Receptor locations were selected according to HEDOP recommendations.
☒	☐	☐	5. All applicable environmental pathways and code options were included and are appropriate for the calculations.
☐	☐	☒	6. Hanford site data were used.
☒	☐	☐	7. Model adjustments external to the computer program were justified and performed correctly.
☐	☐	☒	8. The analysis is consistent with HEDOP recommendations.
☐	☐	☒	9. Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
☒	☐		10. Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "NO" responses must be explained and use of nonstandard methods justified.

Bert Herz DA Himes 7/30/96
HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):

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Consequence Analysis 8M400	Consequence Analysis 8M400	Date 7/30/96
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Consequence Analysis of a Postulated NaOH Release from the 2727-W Sodium Storage Facility		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
C. Carro	A2-34	X			
G.N. Hanson	S5-05	X			
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J.L. Stewart	A2-26	X			
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