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6. Author

Name: G. T. Clark, P.E.
SAIC Consultant
L.L.L. Adams
WHC Cognizant Engineer

G. T. Clark
Signature

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7. Abstract

The requirement for post neutralization filtration of the UO_3 Plant Process Condensate to remove uranium was evaluated. A statistical risk approach was used to determine the requirement. The previous process runs shows the risk of exceeding the 10 CFR 20, Table II, Column 2. Limits is extremely low. The cost of a filter installation is not economically justified to reduce the risk.

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FEASIBILITY STUDY

POST NEUTRALIZATION FILTRATION OF

UO_3 PLANT PROCESS CONDENSATE

G.T. CLARK, P.E.
(SAIC CONSULTANT)

L.L.L. ADAMS
(WHC COGNIZANT ENGINEER)

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1.0 INTRODUCTION

1.1 Scope of Study

The objective of this study is to determine if the uranium content of the UO_3 Plant process condensate effluent has a significant probability of exceeding 10 CFR Ch. 1 (1-1-89 Edition) Part 20, Appendix B, Table II, Column 2 (Table II values) on the release of radionuclides to the environment. Furthermore, if the probability is significant, the objective is to determine if post neutralization filtration of the process condensate is a recommended method of effluent treatment for reducing the probability of exceeding Table II values.

1.2 Background

The UO_3 Plant is a facility that is designed to convert 60 percent uranyl nitrate hexahydrate (UNH) feed solution to an uranium oxide (UO_3) powder (product) and nitric acid (by-product). The processes within the facility are evaporation, calcination, and nitrogen oxide (NO_x) absorption. The evaporation process uses three concentrators that increase the feed to 100 percent UNH solution. The 100 percent UNH solution is kept in a molten state by auxiliary heating and is continuously pumped into up to six calciners where the UNH is exposed to temperatures around 1000 °F and undergoes thermal decomposition to form UO_3 powder. The exhaust gases from the calciners are then routed to the nitric acid absorption process where NO_x is removed from the gas stream with water in a multi-trayed, water cooled, absorption column. Two steam jets are used to control the process equipment vacuum and to remove non condensible vapors. The condensible vapors and steam used in the jets are the principal sources of the process condensate stream.

The only mechanism for directly contaminating the process condensate with uranium while the plant is operating is the condensing of liquid mist which passes through the steam jets. The two condensers are E-D3 and E-B3. The E-D3 condenser only cools the gases from the evaporation process. The E-B3 condenser receives the exhaust gases from both the E-D3 condenser and the nitric acid absorption column. The nitric acid absorption column scrubs the mists from the calcination process and removes the uranium from the system. The uranium is in the mist created in the evaporation process, carried by the concentrator offgas, and condensed in the E-D3 condenser.

The UO_3 Plant has had sixteen process runs since February, 1984. The first fourteen runs, process condensate effluent was discharged to the 216-U-12 Crib. In 1987 and January 1988, the process condensate effluent was modified to improve the neutralization process. The fifteenth run started discharging to the 216-U-17 Crib on February 1, 1988, was concluded on February 6. The average production rate was 26.7 metric tons of uranium per day, the third highest production

rate. The last run occurred during April and May, 1989, and set a record of 29.1 metric tons of uranium per day.

The 1987 process modifications utilized an existing 14,000 gallon surge tank, TK-X37, followed by a 800 gallon batch neutralization tank, TK-C5. (See Figure 1) The surge tank collects all of the process condensate and is mixed by an electric agitator. The neutralization tank is equipped with redundant pH meters and tanks to add 70 percent phosphoric acid and 40 percent potassium hydroxide. Both chemicals will cause a solid suspension of an uranyl form of apatite. (The calcium needed to form the apatite comes from the hardness in the small amounts of raw water added to the process.)

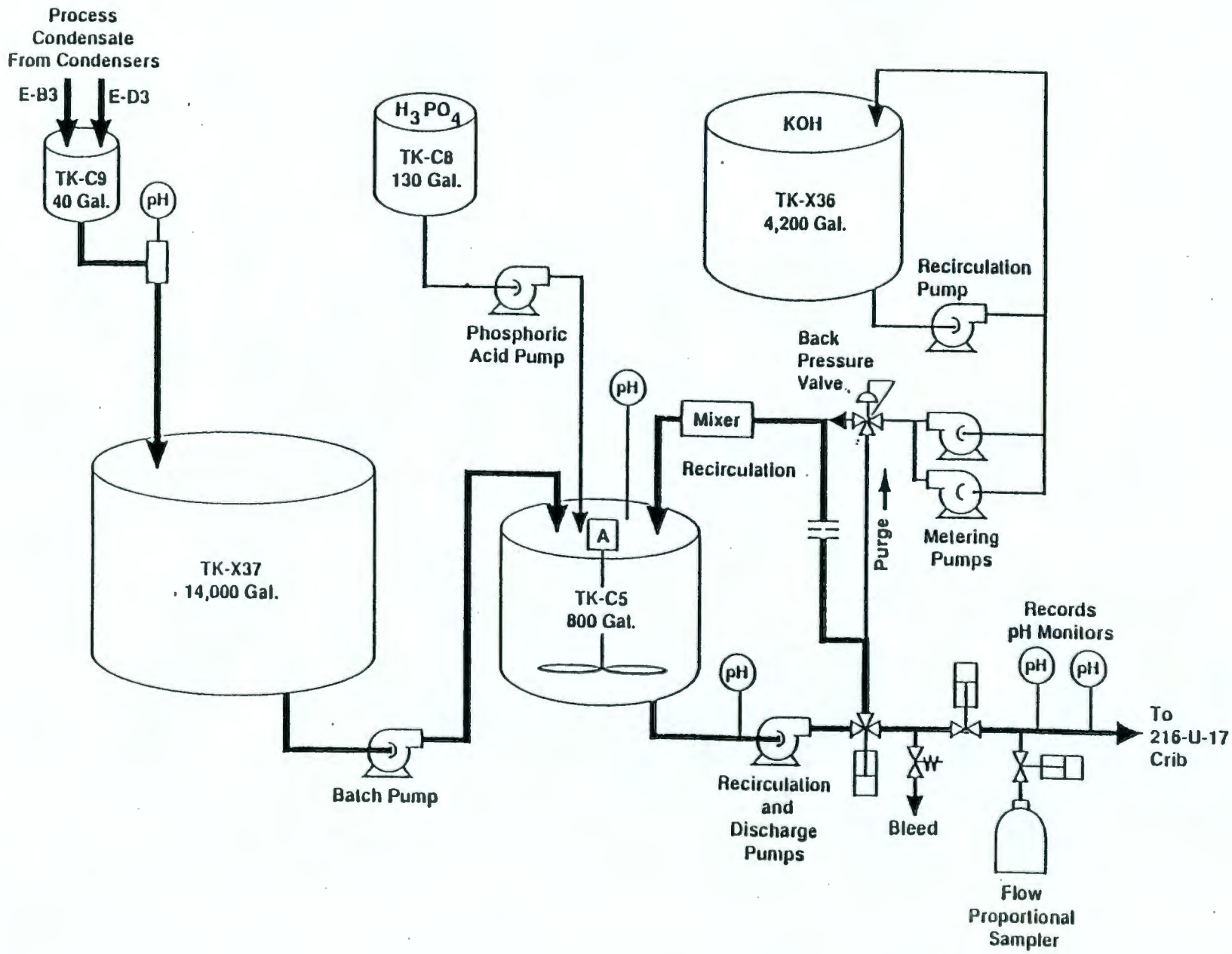
The process effluent control samples used in the study are currently taken from a valve located in the transfer line between the surge tank and the batch neutralization tank. The frequency of sampling during operation periods is one per every third batch to the neutralization tank. Because the neutralization batches are nearly the same size during the run (450 to 500 gallons), the sampling technique can be considered to be flow proportional.

The maximum production rate of condensate is estimated to be 10 gallons per minute. The surge tank has a maximum process capacity of 12,500 gallons. The full damping value of the surge tank has not been utilized by process operations. The volume of liquid in the surge tank has varied between 2,000 and 12,500 gallons. The normal level has been 7,000 to 8,000 gallons. The probability for some concentration spikes exceeding the Table II values and reaching the new 216-U-17 Crib decreases when the surge tank is being operated at high tank volume. The process has an existing capability to improve performance in handling transient peak concentrations.

One additional modification was made to the sampling system between production runs 15 and 16. The sampling point during run 15 was located near a leaky UNH pump. Plant operating logs did report that some UNH liquid was being splashed on the tubing from the sampling pump. Some of the samples were suspected of being contaminated and after the run, the pump was repaired and the sampling point was moved to the Northwest wall of B-Cell.

A modification is being made to the process at the current time. A Fiber Mist Eliminator manufactured by CECO Filters Inc. is being installed between the concentrators and the E-D3 condenser. The purpose of the equipment is to reduce the carry over of uranium bearing mist from the concentrators prior to the vapor entry into the condenser. The equipment was designed by the manufacturer for the process. The manufacturer vendor information states a 100 to 1 reduction in the mist droplets being carried through their equipment. The equipment is currently installed and is being prepared for testing. The actual performance evaluation of this equipment will not be completed for this study.

Figure 1 - UO_3 Plant Process Condensate Neutralization System



1.3 Study Approach

The initial part of this study will be to establish risk criteria limits. The possibility of exceeding a Table II value can never be fully eliminated, it can only be reduced to where added protection can not be economically justified. The purpose of the risk criteria limits is to establish an appropriate decision point. If these limits are exceeded, then the recommendation will be to provide filtration. If the limits are not exceeded, filtration will not be required.

The first criterion limit will be the maximum concentration of uranium that can be found in a sample. Several isotopes of uranium are found in the feed material. The uranium isotope that is normally nearest to the Table II value will be used to estimate the maximum uranium concentration.

The second criterion limit will be to establish the statistical risk that one sample in a population of samples will exceed a Table II value. Risk probability values are normally determined by the number of standard deviations from the average of the sample population.

After the risk criteria limits are established, the statistical processing of past sampling data will be completed. Past experimental filtration data will be evaluated to estimate the effectiveness of the process. The process will be evaluated for any abnormal conditions that may cause unusually high concentrations of uranium. Finally, the uranium concentration from the evaporation process with fiber mist eliminator will be evaluated. Conclusions and recommendations may include process changes in addition to the decision on the requirements for a filter.

2.0 SUMMARY OF RESULTS

The study was made to determine if filtration would be recommended after neutralization of the UO_3 Plant Process Condensate. Calculations based on the most restrictive isotope (U-234) show the maximum uranium allowed in the Process Condensate stream should be .04 grams per liter. For purposes of this study, risk criteria from DOE Order 6430.1A was used to evaluate the probability for exceeding the Table II value. The risk criteria is that a credible event must be greater than one per million per year.

Past process condensate data from 1988 to the present was evaluated and the condensate discharged to the 216-U-17 Crib has never exceeded uranium Table II values. The calculated maximum credible event concentration value for uranium is less than 0.006 grams per liter. These findings show that filtration is not required.

In addition, the study also made recommendations to reduce risk with process operational changes and the use of a fiber mist eliminator, if the equipment is available.

3.0 DISCUSSION

3.1 Risk Criteria Development

3.1.1 Concentration Limit

The UNH feed material has four significant isotopes of uranium; U-238, U-235, U-236 and U-234. All the isotopes have insignificant differences in their physical and chemical properties. An assumption is that the isotopic mix of the uranium in the process condensate is the same as in the feed material.

The most common isotope in the uranium feed is U-238. The UO_3 Plant feed specifications limit the minimum concentration of U-238 to 99.0 percent of the total uranium. The maximum concentration of U-238 is 99.2 percent. Typical isotopic distributions are shown in Table 1.

Table 1

Typical Isotopical Distribution Range Data

Uranium Isotope	Minimum (%)	Maximum (%)
U-238	99.0	99.2
U-235	0.78	0.86
U-236	0.10	0.15
U-234	0.002	0.012

The Table II values for isotopes are expressed as micro Curies per milliliter (uCi/ml). Curies is a function of both the isotope's atomic weight and half life. The Table II values are 4.0 E-5 uCi/ml for U-238 and 3.0 E-5 uCi/ml for the other isotopes.

The calculations in Appendix A, Calculation Set 1, show that U-234 is the isotope most likely to exceed the Table II values. Based on the value for U-234 and the isotopical list above, the maximum uranium concentration should be limited to 0.04 grams per liter.

3.1.2 Risk Limit

For purposes of this study, criteria from the Department of Energy (DOE) regulation, DOE Order 6430.1A, Design Criteria, was used to establish a value limit for risk management. The design criteria requires that new construction install equipment that will mitigate the probability of a credible event. The installation of a

filtration system is new construction for the UO_3 Plant. Credible events have a probability of occurrence greater or equal to 1 per 1,000,000 (1E-6) per year. Therefore, if the probability of one sample, having a concentration of at least 0.04 grams of uranium per liter, exceeds the value, 1E-6, in the only stabilization run scheduled for the next year, then the filter will be required to be installed.

Not exceeding a risk management limit does not imply a filter should not be installed. It does require that the need for equipment be evaluated for its economic benefit to provide public and environmental protection.
Risk is a probability value based upon the unit normal distribution curve where the area under one of the extremities (tails) of the curve is the risk value. The frequency of occurrence on a normal distribution curve is calculated as standard deviations units around the central point of tendency (mean or average). The probability curve is a logarithmic function of standard deviation units and increases in standard deviation units cause significantly less area under the tail of the curve.

The Calculation Set 2 in Appendix A uses the above statistics theory to calculate the limit for risk management. The limit is given in standard deviation units. The calculation shows that if the mean uranium concentration for a population of samples (estimated 120 samples) is less than 6 standard deviation units from .04 grams per liter, then the filter shall be required.

3.2 Previous Analytical Results

Prior to 1988, some samples were obtained that had uranium concentrations greater than the Table II values. These samples were either the result of transitory variations in the process effluent or the lack of proper sampling technique. All of this effluent was sent to the inactive 216-U-12 Crib. The samples collected since the process modifications completed in January, 1988, have not had one sample exceeding Table II values.

The production runs prior to January 1988 would not be a valid comparison for determining probability. The most significant change was the installation of the agitated surge tank. The surge tank provides significant dampening of transient peak concentration values sometimes found before the modifications.

Only two runs were completed since January, 1988, Runs 15 and 16. Run 15 is shown in Appendix A Table 1 and has 82 sample data points. Run 16 is shown in Appendix A Table 2 and has 157 data points. The U-234 concentration for these runs was lower than the maximum in Table 1 above.

The uranium concentration Table II value based on the isotopical distribution of the feed was calculated to be .07 grams of uranium

per liter for each of these runs. No data point exceeded the uranium concentration limit previously established in Section 3.1.1, therefore, the limit value of .04 grams of uranium provides a small amount of conservatism in the risk limit.

Both runs were evaluated by the Process Laboratories and Technology, Statistics Team. The report," Statistical Analysis of UO_3 Plant Process Condensate Data ", dated July 31, 1991, is in Appendix B. The findings were that neither run was a normal distribution.

Run 15 had a significant spread of data points as shown in Figure 1 of the Statistic Team report. Secondly, the fluctuation in concentration was much more variable than in Run 16 for consecutive samples. This variability would not commonly be found in samples taken after a large agitated surge tank. Finally, Run 15 had increasing concentration values as the run progressed. All of these observations are indicators that the samples were being contaminated with UNH solution on the sampling tube as reported in the operation logs. Based upon the evidence, Run 15 is not valid data for preparing a study. Run 15 was not used for further analysis.

Many times process concentration data has a marked skewness to the right on a normal distribution curve. This is partly due to natural physical phenomena such as vapor pressure relationships that are logarithmic functions. In many cases, the logarithms of the data will follow a normal distribution. The Statistics Team does not show any evidence that this type of evaluation was made for Run 16. Appendix A Table 3 is a computer spread sheet analysis of Run 16. The data shows good results with a log normal distribution. The calculations show that for Run 16 the concentration value, six standard deviations above the mean, is 0.0057 grams per liter. Section 3.1 establishes .04 grams per liter as the Risk Management Limit.

3.3 Filter Experimental Test Evaluation

In 1988, the process condensate from the UO_3 Plant was tested with filtration studies. The tests were performed by the Westinghouse Process Chemistry Laboratories. The report " Uranium Solids Formation Resulting From Neutralization of UO_3 Process Condensate ", dated August 15, 1988, is in Appendix B. Tests show that approximately 75 percent of the uranium can be removed with laboratory filters. The laboratory filters were 0.45 micron. Industrial filters are seldom less than 1 micron. The particle removal efficiency of an industrial filter would be less than what is reported.

3.4 Process Characteristic Evaluation

The operation of the process since the 1987-88 modifications has been limited to two runs. Process characteristics must be evaluated, in addition to operating data, to identify potential operational risks.

Current operational procedures will be evaluated to identify ways of mitigating risk.

The evaporation process is usually stable with very little variation in operation. However, the evaporation of the UNH solution is performed under reduced pressure. The evaporation rate can change significantly with variations in pressure. The most critical dynamic situation caused by pressure variations will occur during start-up of evaporation equipment. If the steam jets were started after the liquid in the evaporators were heated, then the liquid would be superheated and a large evolution of vapor would boil into the condensers. The surge of liquid carryover to the condensers would generally be short in duration, 10 minutes or less. The concentration of uranium in the liquid would be high compared to normal operating conditions. This problem has not occurred in the previous sixteen runs.

The operating procedures are written to eliminate the high mist carryover condition. The operating procedures specify the vacuum from the steam jets must reach an equilibrium pressure before the concentrators are filled with liquid.

The Tk-X37 surge tank was installed to dampen concentration variations due to varying pressure conditions in the evaporation equipment. The more liquid in the surge tank, the less the impact of transient peak conditions in liquid carryover. A surge tank operating at a 12,500 gallon capacity will have approximately 6 times less peak concentration values than a surge tank with 2,000 gallons. Procedures on the operation of the surge tank are currently being reviewed. The minimum volume in the surge tank is expected to be increased to 6000 gallons.

3.5 Fiber Mist Eliminator Evaluation

The manufacture, CECO Filters Inc., vendor information on the fiber mist eliminator says the equipment will eliminate 99 percent of the liquid droplets being carried to the process condensers. The liquid droplets are the media for carrying uranium and most other radionuclides. Uranium is a non-volatile material. The estimated reduction in the uranium is estimated to be 100 to 1.

4.0 CONCLUSIONS

The evaluation of Run 16 data shows that a filter would not be required. The operation of the process has some capacity to reduce the risk of exceeding Table II values. The surge tank can be operated at higher capacity. If the fiber mist eliminator is installed, the equipment can be placed in service to significantly reduce uranium concentrations in the condensate.

5.0 RECOMMENDATIONS

The results of the study indicate the likelihood of exceeding the Table II values is extremely small. Installation of a post neutralized Process Condensate filter is not recommended as the marginal reduction in uranium content by this method is not a justifiable benefit as compared to the expense incurred.

The UNH concentrator operating procedure should be evaluated as to its adequacy in providing instruction to the system operators which minimizes the risk of an upset condition which could potentially lead to increased uranium carryover in the off-gas stream.

The minimum operating volume in the surge tank needs to be increased. The additional volume of water will dampen transient variations in uranium concentration.

A Tri-Party Agreement (TPA) milestone to install a fiber mist eliminator downstream of the concentrator vapor outlet nears completion. This system is designed to remove uranium bearing mists from the concentrator off-gas streams with a potential reduction of up to 100. This project was originally slated for a mid-1993 completion and was moved up to December 1991. An aggressive construction schedule has led to an even earlier completion date. Assuming operational testing of the system is successfully completed, it will be operational during the October stabilization campaign; however, it is recognized that this condition is not a requirement to operate the facility under Table II values.

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APPENDIX A

DATA AND CALCULATIONS

APPENDIX A TABLE 1

RUN #15- UO3 PLANT PRE-NEUTRALIZED PROCESS CONDENSATE SAMPLES (TK-X-37)

DATE	TIME	SAMPLE #	URANIUM (g/l)	pH
02/01/88	1335	U2288	1.84E-04	1.96
02/01/88	1400	U2289	1.83E-04	1.86
02/01/88	1418	U2290	2.14E-04	1.86
02/01/88	1430	U2291	2.32E-04	1.87
02/01/88	1445	U2292	2.28E-04	1.87
02/01/88	1500	U2293	1.34E-04	1.88
02/01/88	1517	U2294	1.77E-04	1.90
02/01/88	1738	U2295	2.26E-04	1.93
02/01/88	1755	U2296	3.12E-04	1.94
02/01/88	1812	U2297	2.23E-04	1.95
02/01/88	1824	U2298	1.65E-04	1.97
02/01/88	1840	U2299	1.84E-04	1.96
02/02/88	213	U2300	7.48E-03	1.68
02/02/88	228	U2301	1.14E-02	1.65
02/02/88	252	U2302	1.74E-02	1.22
02/02/88	313	U2307	1.03E-03	1.11
02/02/88	849	U2308	8.66E-04	0.94
02/02/88	917	U2309	4.50E-04	0.93
02/02/88	941	U2310	4.49E-04	0.93
02/02/88	1001	U2311	4.49E-04	0.93
02/02/88	1022	U2312	4.87E-04	0.93
02/02/88	1043	U2313	4.78E-04	0.93
02/02/88	1300	U2314	4.87E-04	0.95
02/02/88	1323	U2315	2.78E-04	0.97
02/02/88	1345	U2316	5.68E-04	0.95
02/02/88	1407	U2317	3.74E-04	0.98
02/02/88	1430	U2318	6.91E-04	1.00
02/02/88	1455	U2319	2.44E-04	1.01
02/02/88	1728	U2320	4.84E-04	1.05
02/02/88	1755	U2321	3.78E-04	1.06
02/02/88	1815	U2336	7.78E-04	1.06
02/03/88	315	U2337	8.57E-04	0.75
02/03/88	345	U2338	1.20E-03	1.00
02/03/88	405	U2339	6.81E-04	0.70
02/03/88	645	U2340	7.42E-04	0.74
02/03/88	720	U2341	7.08E-04	0.73
02/03/88	830	U2342	5.30E-04	0.66
02/03/88	1330	U2343	1.30E-03	0.66
02/03/88	1400	U2344	1.02E-03	0.58
02/03/88	1445	U2345	9.37E-04	0.61
02/03/88	1510	U2346	8.00E-04	0.62
02/03/88	1645	U2347	8.13E-04	0.61
02/03/88	1715	U2348	7.87E-04	0.62

APPENDIX A TABLE 1
(Continued)

DATE	TIME	SAMPLE #	URANIUM	pH
02/03/88	2015	U2349	7.19E-04	0.62
02/03/88	2055	U2350	6.34E-04	0.61
02/03/88	2125	U2351	8.94E-04	0.60
02/03/88	2245	U2352	8.13E-04	0.62
02/03/88	2325	U2353	7.72E-04	0.61
02/04/88	50	U2354	7.08E-04	0.89
02/04/88	135	U2355	7.00E-04	0.61
02/04/88	152	U2361	7.67E-04	0.61
02/04/88	220	U2362	7.60E-04	0.62
02/04/88	255	U2363	6.96E-04	0.62
02/04/88	432	U2364	1.22E-03	0.60
02/04/88	505	U2365	7.49E-04	0.59
02/04/88	530	U2366	9.30E-04	0.63
02/04/88	603	U2367	1.19E-03	0.60
02/04/88	637	U2368	6.34E-04	0.59
02/04/88	708	U2369	8.00E-04	0.63
02/04/88	813	U2370	9.36E-04	0.60
02/04/88	844	U2371	4.29E-04	0.55
02/04/88	912	U2372	8.05E-04	0.59
02/04/88	947	U2373	3.11E-03	0.60
02/04/88	1100	U2374	3.07E-02	0.58
02/04/88	1125	U2375	2.01E-02	0.59
02/04/88	1310	U2380	1.17E-03	0.60
02/04/88	1345	U2381	3.48E-03	0.60
02/04/88	1415	U2382	1.69E-02	0.62
02/04/88	1450	U2383	4.47E-03	0.59
02/04/88	1635	U2384	7.32E-04	0.57
02/04/88	1705	U2385	1.64E-03	0.61
02/04/88	1735	U2386	2.04E-03	0.60
02/04/88	1805	U2387	1.07E-03	0.60
02/04/88	1915	U2388	3.13E-03	0.58
02/04/88	1940	U2389	2.45E-03	0.60
02/04/88	2005	U2390	1.23E-03	
02/04/88	2035	U2391	2.50E-03	0.59
02/04/88	2105	U2392	1.62E-03	
02/04/88	2130	U2393	2.41E-03	
02/04/88	2200	U2394	7.03E-03	0.59
02/04/88	2230	U2395	3.26E-03	0.58
02/05/88	200	U2298	4.72E-06	

APPENDIX A TABLE 2

RUN #16- UO3 PLANT PRE-NEUTRALIZED PROCESS CONDENSATE SAMPLES (TK-X-37)

DATE	TIME	SAMPLE #	URANIUM (g/l)	pH
04/18/89	1345	U3153	3.24E-04	2.31
04/20/89	1130	U3168	3.51E-04	1.89
04/20/89	1204	U3169	2.11E-04	1.88
04/20/89	1234	U3170	1.76E-04	1.77
04/20/89	1305	U3171	2.18E-04	1.88
04/20/89	1345	U3172	2.11E-04	1.88
04/20/89	1550	U3173	4.30E-04	1.45
04/20/89	1910	U3174	5.62E-04	1.29
04/20/89	2220	U3175	5.29E-04	1.16
04/21/89	125	U3176	5.62E-04	1.20
04/21/89	335	U3177	5.62E-04	1.11
04/21/89	1005	U3200	7.02E-04	1.07
04/21/89		U3201	9.63E-04	1.02
04/21/89		U3202	7.49E-04	1.01
04/21/89		U3203	7.25E-04	1.02
04/21/89		U3204	7.98E-04	1.00
04/21/89		U3205	8.43E-04	1.06
04/21/89		U3206	7.75E-04	1.04
04/21/89		U3207	9.84E-04	1.00
04/21/89		U3208	5.95E-04	1.08
04/21/89		U3209	6.13E-04	1.06
04/21/89	1210	U3210	6.74E-04	1.03
04/21/89	1415	U3211	6.47E-04	1.01
04/21/89	1745	U3212	7.15E-04	1.14
04/21/89	2240	U3213	8.43E-04	0.99
04/22/89	250	U3214	7.82E-04	0.98
04/22/89	515	U3215	6.74E-04	0.93
04/22/89	742	U3216	7.66E-04	0.88
04/22/89	915	U3217	7.22E-04	0.91
04/22/89	1110	U3218	7.35E-04	0.81
04/22/89	1445	U3219	8.24E-04	0.97
04/22/89	1550	U3220	8.14E-04	0.94
04/22/89	1735	U3221	9.30E-04	0.98
04/22/89	2013	U3222	8.99E-04	0.94
04/22/89	2243	U3223	9.69E-04	1.03
04/23/89	105	U3224	9.54E-04	1.00
04/23/89	320	U3225	8.24E-04	1.00
04/23/89	615	U3226	9.63E-04	0.98
04/23/89	930	U3227	9.63E-04	1.05
04/23/89	1130	U3228	9.30E-04	1.00
04/23/89	1400	U3229	8.62E-04	0.98
04/24/89		U3261	9.51E-04	0.98
04/24/89		U3262	9.08E-04	0.96
04/24/89	1600	U3263	9.57E-04	1.09
04/24/89	1915	U3264	9.99E-04	1.04
04/24/89	2115	U3265	9.94E-04	1.02

APPENDIX A TABLE 2
(Continued)

DATE	TIME	SAMPLE #	URANIUM	pH
04/24/89		U3266	9.69E-04	1.19
04/24/89		U3267	1.00E-03	1.16
04/24/89		U3268	9.37E-04	1.06
04/24/89		U3269	1.16E-03	1.00
04/24/89		U3270	9.74E-04	1.06
04/25/89		U3281	8.24E-04	1.01
04/25/89		U3282	8.62E-04	0.98
04/25/89		U3283	8.62E-04	0.98
04/25/89		U3284	1.00E-03	1.14
04/25/89		U3285	9.69E-04	1.10
04/25/89		U3286	1.04E-03	1.08
04/25/89		U3287	8.14E-04	1.02
04/25/89		U3288	8.53E-04	1.08
04/25/89		U3289	7.87E-04	1.03
04/25/89		U3290	8.53E-04	1.00
04/26/89		U3301	7.75E-04	1.00
04/26/89		U3302	8.74E-04	1.02
04/26/89		U3303	9.44E-04	1.05
04/26/89		U3304	9.51E-04	0.99
04/26/89	1205	U3305	8.91E-04	1.05
04/26/89	1400	U3306	8.53E-04	1.02
04/26/89	1545	U3307	8.14E-04	1.00
04/26/89	1915	U3308	8.24E-04	1.00
04/26/89	2000	U3309	8.62E-04	1.19
04/26/89		U3310	7.83E-04	1.06
04/26/89		U3325	8.91E-04	1.00
04/26/89		U3326	8.65E-04	0.98
04/26/89		U3327	5.82E-04	1.07
04/26/89		U3328	6.87E-04	1.00
04/26/89		U3329	6.66E-04	1.02
04/26/89		U3330	8.91E-04	1.09
05/08/89	1451	U3331	3.26E-04	1.70
05/09/89	245	U3332	1.58E-04	1.92
05/09/89	610	U3333	3.81E-04	1.42
05/09/89	922	U3334	5.99E-04	1.17
05/03/89		U3409	2.70E-04	1.74
05/07/89		U3489	3.17E-04	
05/09/89	1223	U3545	8.43E-04	1.07
05/09/89	1630	U3546	8.08E-04	1.13
05/09/89	2045	U3547	7.25E-04	1.04
05/09/89	2344	U3548	5.99E-04	1.13
05/10/89	255	U3549	5.44E-04	1.07
05/10/89	550	U3550	5.97E-04	1.05
05/10/89	841	U3551	7.25E-04	1.04
05/10/89	1103	U3552	7.49E-04	1.01
05/10/89	1319	U3553	8.03E-04	1.07
05/10/89	1653	U3554	9.08E-04	1.04
05/10/89	1853	U3555	8.43E-04	0.97

APPENDIX A TABLE 2
(Continued)

DATE	TIME	SAMPLE #	URANIUM	pH
05/10/89	2220	U3556	8.78E-04	0.84
05/11/89	18	U3557	7.75E-04	0.84
05/11/89	237	U3558	8.65E-04	0.82
05/11/89	456	U3559	7.63E-04	0.87
05/11/89	640	U3560	8.53E-04	1.00
05/11/89	740	U3561	8.33E-04	0.96
05/11/89	1030	U3562	1.08E-03	0.93
05/11/89	1310	U3563	8.33E-04	0.90
05/11/89	1700	U3564	7.93E-04	0.94
05/11/89	1950	U3585	7.58E-04	0.91
05/11/89	2130	U3586	7.25E-04	0.94
05/11/89	2307	U3587	8.06E-04	0.99
05/12/89	45	U3588	8.03E-04	0.84
05/12/89	242	U3589	8.65E-04	0.79
05/12/89	435	U3590	8.03E-04	0.72
05/12/89	630	U3591	8.03E-04	0.65
05/12/89	824	U3592	7.49E-04	0.62
05/12/89	1007	U3593	9.51E-04	0.63
05/12/89	1142	U3594	7.78E-04	0.86
05/11/89		U3595	7.03E-04	0.96
05/12/89	1419	U3596	7.78E-04	0.80
05/12/89	1707	U3597	7.70E-04	0.70
05/12/89	2000	U3598	7.43E-04	0.93
05/12/89	2342	U3599	4.12E-04	0.90
05/13/89	143	U3600	6.23E-04	0.98
05/13/89	440	U3601	8.24E-04	0.92
05/13/89	735	U3602	8.33E-04	0.90
05/13/89	1015	U3603	8.63E-04	0.89
05/13/89	1214	U3604	8.74E-04	0.88
05/13/89	1610	U3632	8.03E-04	0.99
05/13/89	1725	U3633	7.83E-04	0.95
05/13/89	1840	U3634	6.89E-04	0.89
05/13/89	2055	U3635	8.54E-04	0.94
05/13/89	2310	U3636	7.23E-04	0.85
05/14/89	100	U3637	6.74E-04	0.80
05/14/89	220	U3638	6.74E-04	0.78
05/14/89	420	U3639	7.49E-04	0.76
05/14/89	640	U3640	7.12E-04	0.75
05/14/89	900	U3641	7.12E-04	0.74
05/14/89	1117	U3648	7.87E-04	0.69
05/14/89	1341	U3649	7.22E-04	0.86
05/14/89	1605	U3650	6.42E-04	0.87
05/14/89	1830	U3651	7.17E-04	0.91
05/14/89	2053	U3652	7.17E-04	0.83
05/15/89	28	U3653	7.56E-04	0.90
05/15/89	140	U3654	7.64E-04	0.68
05/15/89	337	U3655	7.64E-04	0.66
05/15/89	555	U3656	7.64E-04	0.65
05/15/89	808	U3657	7.64E-04	0.69

APPENDIX A TABLE 2
(Continued)

DATE	TIME	SAMPLE #	URANIUM	pH
05/15/89	1024	U3666	7.64E-04	
05/15/89	1241	U3667	7.42E-04	0.81
05/15/89	1436	U3668	7.42E-04	0.76
05/15/89	1715	U3669	8.20E-04	0.70
05/15/89	1930	U3670	7.78E-04	1.04
05/15/89	2150	U3671	7.70E-04	1.01
05/16/89	30	U3672	7.78E-04	0.98
05/16/89	225	U3673	4.97E-04	0.92
05/16/89	505	U3674	3.85E-04	0.90
05/16/89	753	U3675	3.43E-04	0.90
05/16/89	914	U3711	6.66E-04	0.90
05/16/89	1129	U3712	6.92E-04	0.92
05/16/89	1356	U3713	6.79E-04	0.93
05/16/89	1613	U3714	7.02E-04	0.89

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Suite 240 1835 Terminal Drive
RICHLAND, WASHINGTON 99352
(509) 943-3133

JOB Calculation Set 1
SHEET NO 1 OF 4
CALCULATED BY G. Thomas Clark DATE Aug 15 1991
CHECKED BY [illegible] DATE 5/15/91
SCALE

WHC-SD-CP-ES-144, Rev. 0

PROBLEM: GIVEN THE NRC LIMITS, WHAT URANIUM ISOTOPE WILL ESTABLISH THE CONCENTRATION LIMIT FOR URANIUM?

	NRC LIMIT	LIMIT IN ($\mu C_i/L$)
U-233	4×10^{-5} $\mu C_i/ML$	4×10^{-2}
U-235	3×10^{-5}	3×10^{-2}
U-236	3×10^{-5}	3×10^{-2}
U-234	3×10^{-5}	3×10^{-2}

APPROACH IS TO USE THE WORST CASE CONCENTRATION FOR EACH INDIVIDUAL ISOTOPE. (NOTE THE SUM OF PERCENTAGES ARE GREATER THAN 100%)

FROM TABLE 1 OF THE REPORT

URANIUM 238

		DATA
	MCU	238.05
	½ LIFE	1.42×10^{17} SEC *
FROM REPORT (MAX %)	% ISOTOPE	99.2%

* ½ LIFE DATA WAS OBTAINED FROM A RECENT VOLUME OF THE HANDBOOK OF CHEMISTRY AND PHYSICS. THE DATA IN THE HANDBOOK WAS IN YEARS. THE CONVERSION TO SECONDS IS AS FOLLOWS.

$$\text{SECONDS} = (\text{HANDBOOK DATA IN YRS}) \times \left(\frac{365\ \text{DAYS}}{\text{YR}}\right) \times \left(\frac{24\ \text{HRS}}{\text{DAY}}\right) \times \left(\frac{[illegible]}{[illegible]}\right)$$

$$4\ C_i/L = (10^{-6}) \times \frac{4\ C_i}{L}$$

LIMIT FOR U238 $= 4 \times 10^{-6}\ C_i/L$

CHANGING THE LIMIT TO [illegible] THE FOLLOWING FORMULA IS USED:

$$\text{CURIES} = (\text{Volume of [illegible]}) \times \left(\frac{[illegible]}{\text{MCU}}\right) \times \left(\frac{[illegible]}{\text{½ LIFE [illegible]}}\right) \times \left(\frac{1}{[illegible]}\right)$$

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Suite 240 1835 Terminal Drive
RICHLAND, WASHINGTON 99352
(509) 943-3133

JOB: Calculation Set 1
SHEET NO. 2 OF 4
CALCULATED BY: G. Thomas Clark DATE: Aug 15 1991
CHECKED BY: [illegible] DATE: 8/5/91
SCALE:

WHC-SD-CP-ES-144, Rev. 0

THE BASIS OF THE CALCULATION IS ONE LITER OF LIQUID.

EXPLANATION OF THE FORMULA:

THE FORMULA IS DERIVED FROM THE DECAY EQUATION:

$$-\frac{dN}{dt} = \lambda(N)$$

THE INTEGRAL:

$$\ln(N) - \ln(N_0) = -\lambda(t - t_0)$$

OR $\ln\left(\frac{N}{N_0}\right) = -\lambda t$

THE RATIO $\frac{N}{N_0} = \frac{1}{2}$

$$-\ln\left(\tfrac{1}{2}\right) = \ln(2)$$

3.7×10^{10} IS THE (DISINTEGRATIONS/SEC)/Ci (DEFINITION OF CURIE)

6.02×10^{23} IS AVOGADRO'S NUMBER OR MOLECULES/MOLE

λ = the constant expressed for ½ LIFE

REARRANGEMENT OF THE EQUATION

$$(\text{grams of material/liter}) = (\text{curies/liter}) \times \frac{(\frac{1}{2}\text{ LIFE})}{\ln(2)} \times \left(\frac{\text{MW}}{6.02 \times 10^{23}}\right) \times (3.7 \times 10^{10})$$

$$= (\text{curies/liter}) \times \frac{(\frac{1}{2}\text{ LIFE})(\text{MW})}{1.1278 \times 10^{13}}$$

DETERMINE THE GRAMS OF URANIUM 238 (U-238) THAT IS EQUIVALENT TO THE NRC LIMIT

$$\text{NRC LIMIT} = (\text{grams/liter}) = (4 \times 10^{-8}\ \text{Ci/L}) \times \frac{(4.2 \times 10^{17})(238.03)}{1.1278 \times 10^{13}}$$

$$= (0.12\ \text{gm/liter}) \text{ of U-238}$$

DETERMINE THE GRAMS OF TOTAL URANIUM IF U-238 IS 99.3%

$$\text{TOTAL} = \frac{0.12\ \text{gm/liter}}{0.992} = \frac{0.12}{0.992} = 0.121\ \text{gm/liter}$$

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Suite 240 1835 Terminal Drive
RICHLAND, WASHINGTON 99352
(509) 943-3133

JOB: [illegible] SET 1
SHEET NO. 3 OF 4
CALCULATED BY [illegible] DATE Aug 15 [illegible]
CHECKED BY [illegible] DATE 8/15/91
SCALE

WHC-SD-CP-ES-144, Rev. 0

DETERMINE U-235

URANIUM 235

	DATA
MW	235.04
½ LIFE	2.24×10^{16} sec
% ISOTOPE	0.86%

FROM REPORT (MAX %)

SIMILIAR CALCULATIONS NRC LIMIT = 3×10^{-8} Ci/L

$$\text{NRC LIMIT as (gram/liter)} = \left(3 \times 10^{-8}\,\frac{Ci}{L}\right)\frac{(2.24 \times 10^{16})(235.04)}{1.1278 \times 10^{13}}$$
$$= 0.014 \text{ gm/liter as U-235} \quad ✓$$

DETERMINE THE TOTAL EQUIVALENT U URANIUM IS THE WT% = 0.86%

$$\text{TOTAL U} = \frac{0.014}{0.0086} = 1.63 \text{ grams/liter}$$

DETERMINE U-236

URANIUM 236

	DATA
MW	236.05
½ LIFE	7.54×10^{14} sec
% ISOTOPE	0.15%

FROM REPORT (MAX %)

$$\text{NRC LIMIT as (gram/liter)} = \left(3 \times 10^{-8}\,\frac{Ci}{L}\right)\frac{(7.54 \times 10^{14})(236.05)}{1.1278 \times 10^{13}}$$
$$= 0.00473 \text{ gm/liter as U-236} \quad ✓$$

DETERMINE THE TOTAL EQUIVALENT U URANIUM IS THE WT% = 0.15%

$$\text{TOTAL U} = \frac{0.00473}{0.0015} = 3.15 \text{ gm/liter}$$

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Suite 240 1835 Terminal Drive
RICHLAND, WASHINGTON 99352
(509) 943-3133

JOB: Calculation Set 1
SHEET NO. 4 OF 4
CALCULATED BY: G. Thomas Clark DATE: Aug 15, 79
CHECKED BY: [illegible] DATE: 8/5/79
SCALE:

WHC-SD-CP-ES-14.4, Rev. 0

DETERMINE U-234

URANIUM 234

		DATA
	MW	234.04
	1/2 LIFE	7.79×10^{12}
FROM REPORT (MAX %)	% ISOTOPE	0.012%

NRC LIMIT as (grams/liter) $= \left(3 \times 10^{-8} \frac{Ci}{L}\right) \frac{(7.79 \times 10^{12})(234.04)}{1.1278 \times 10^{13}}$

$= 0.00000485$ gms U-234/liter ✓

DETERMINE THE TOTAL EQUIVALENT U WHEN U-234 IS W% = 0.012%

TOTAL U/liter $= \frac{0.00000485}{0.00012} = 0.04$ gms of U/liter

SUMMARY

	NRC LIMIT	as U/liter
U-233	4×10^{-5} μCi/ml	0.121 gms/liter
U-235	3×10^{-5} μCi/ml	1.63 gms/liter
U-236	3×10^{-5} μCi/ml	.316 gms/liter
U-234	3×10^{-5} μCi/ml	.040 gms/liter

THE U-234 ALLOWS THE LOWEST MAXIMUM CONCENTRATION THEREFORE, IT IS THE MOST LIMITING CONDITION.

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1845 Terminal Drive, Suite 202
Richland, Washington 99352
(509) 943-3133

JOB CALCULATION SET 2
SHEET NO. 1 OF 2
CALCULATED BY C THOMAS CLARK DATE AUG 2, 1991
CHECKED BY [illegible] DATE 5/14/91
SCALE

WHC-SD-CP-ES-144, REV. 0

ASSUME THE FOLLOWING DOE ORDER 6430.1A CRITERIA APPLIES: IF ACCIDENT HAS AN ESTIMATED PROBABILITY OF OCCURENCE > 10^{-6}/YEAR IT CAN BE CONSIDERED A NON CREDIBLE OCCURANCE.

PROBLEM: WHAT IS THE PROBABILITY OF A SAMPLE VIOLATING TABLE II LIMITS DURING THE NEXT UO_3 RUN.

INFORMATION NEEDED TO SOLVE PROBLEM

HOW MANY SAMPLES NEXT YEAR

FACT 1 1 RUN SCHEDULED, DURATION ~ 4 WEEKS AND NO WEEKEND OPERATION

NORMAL RUN AVERAGES 2 SAMPLES PER SHIFT OR 6 SAMPLES PER DAY.

TOTAL NUMBER OF SAMPLES NEXT YEAR = 6 x 4 x 5 = 120

FACT 2 THE PROBABILITY EQUATION IS EXPRESSED AS FOLLOWS:

$$1.00 = (\text{PROBABILITY OF SUCCESSFUL SAMPLES}) + (\text{PROBABILITY OF ONE OR MORE SAMPLES} > \text{TABLE II})$$

$$1.00 = P + Q$$

$$Q = 0.000001$$

$$P = (\text{PROBABILITY OF SUCCESS EACH SAMPLE})^{120} = p^{120}$$

$$p^{120} = 0.999999$$

$$p = (0.999999)^{1/120} = 0.9999999917$$

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JOB
SHEET NO. 2 OF 2
CALCULATED BY G THOMAS CLARK DATE AUG 2, 199
CHECKED BY KR Ridgway DATE 3/16/91
SCALE

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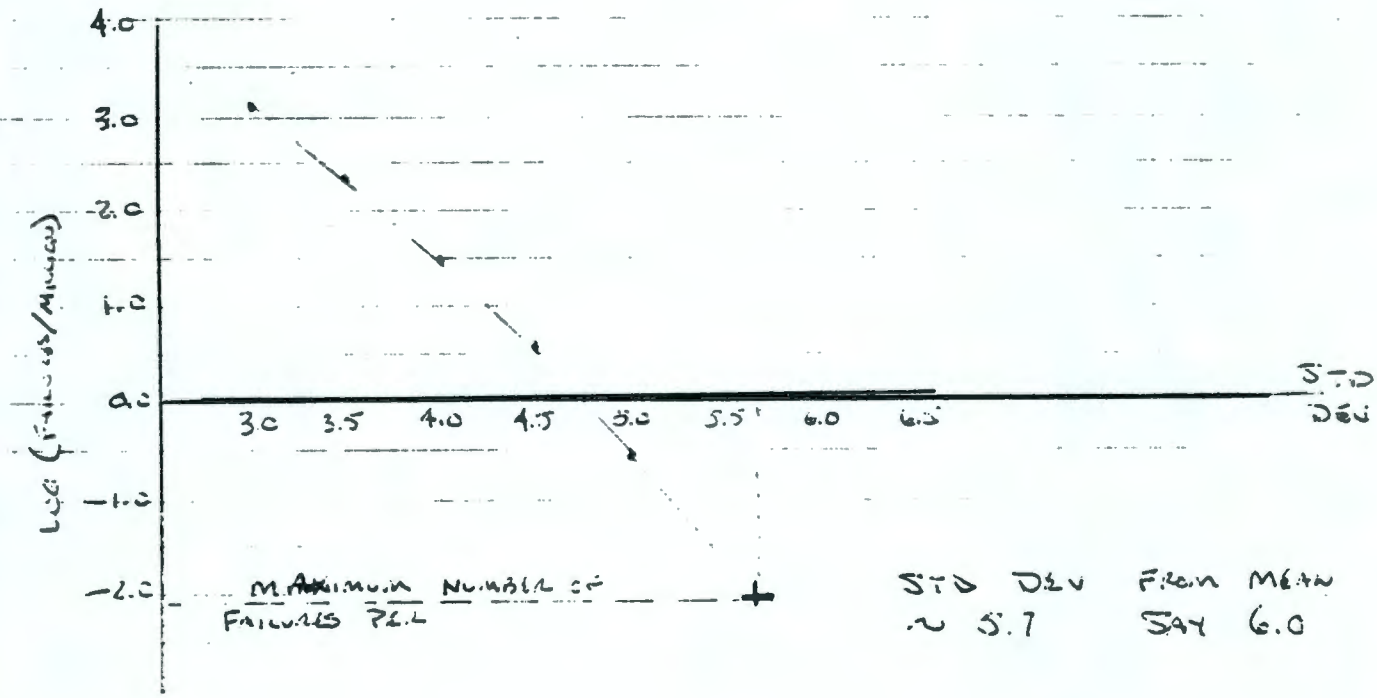
THE ALLOWABLE FAILURE (q) PER SAMPLE IS

$$q = 1.0 - p = 0.0083 \times 10^{-6} \text{ or } 0.0083 \frac{\text{FAILURES}}{\text{MILLION}}$$

$$\text{LOG}(0.0083) = -2.08$$

WAUGH, STATISTICAL TABLES AND PROBLEMS 3ED, McGRAW HILL CO. 1952
EXTRAPOLATION DATA:

STD DEV.	FAILURES/MILLION	LOG (FAILURES/MILLION)
3.0	1350	3.13
3.5	233	2.37
4.0	31.7	1.50
4.5	3.4	.53
5.0	.2867	-.543



CONCLUSION IS THAT IF THE TABLE II LIMITS ARE MORE THAN 6 STANDARD DEVIATIONS FROM THE MEAN VALUE FOR A POPULATION OF SAMPLES, THEN THE POSSIBILITY OF VIOLATING TABLE II LIMITS IS A NON CREDIBILE EVENT. DOE ORDER 6430 1A ALLOWS US THE ABILITY TO DISREGARD NON CREDIBILE EVENTS

APPENDIX A TABLE 3

STATISTICAL EVALUATION OF RUN 16

SAMPLE #	CONC.	VARIANCE	Ln(Conc.)	VARIANCE
U3153	.000324	.0000002	-8.034767	.6281449
U3168	.000351	.0000002	-7.95472	.5076751
U3169	.000211	.0000003	-8.463651	.4919189
U3170	.000176	.0000003	-8.645021	.9678912
U3171	.000218	.0000003	-8.431011	.4132559
U3172	.000211	.0000003	-8.463651	.4919189
U3173	.00043	.0000001	-7.75172	.2596048
U3174	.000562	.0000000	-7.48400	.0584661
U3175	.000529	.0000000	-7.54452	.091392
U3176	.000562	.0000000	-7.48400	.0584661
U3177	.000562	.0000000	-7.48400	.0584661
U3200	.000702	.0000000	-7.26157	.000375
U3201	.000963	.0000000	-6.94545	.0880629
U3202	.000749	.0000000	-7.19677	.0020648
U3203	.000725	.0000000	-7.22933	.0001657
U3204	.000798	.0000000	-7.133402	.0118394
U3205	.000843	.0000000	-7.07854	.0267871
U3206	.000775	.0000000	-7.16264	.0063304
U3207	.000984	.0000001	-6.92388	.1013317
U3208	.000595	.0000000	-7.42694	.0341281
U3209	.000613	.0000000	-7.39714	.0240047
U3210	.000674	.0000000	-7.30228	.0036083
U3211	.000647	.0000000	-7.34316	.0101915
U3212	.000715	.0000000	-7.243228	.000001
U3213	.000843	.0000000	-7.07854	.0267871
U3214	.000782	.0000000	-7.15365	.007842
U3215	.000674	.0000000	-7.30228	.0036083
U3216	.000766	.0000000	-7.17432	.0046081
U3217	.000722	.0000000	-7.23348	.0000761
U3218	.000735	.0000000	-7.21564	.000706
U3219	.000824	.0000000	-7.10134	.0198447
U3220	.000814	.0000000	-7.11355	.0165536
U3221	.00093	.0000000	-6.980326	.0685838
U3222	.000899	.0000000	-7.01422	.0519765
U3223	.000969	.0000000	-6.93924	.0917879
U3224	.000954	.0000000	-6.95484	.0825782
U3225	.000824	.0000000	-7.10134	.0198447
U3226	.000963	.0000000	-6.94545	.0880629
U3227	.000963	.0000000	-6.94545	.0880629
U3228	.00093	.0000000	-6.980326	.0685838
U3229	.000862	.0000000	-7.05625	.0345796
U3261	.000951	.0000000	-6.95799	.0807779
U3262	.000908	.0000000	-7.00426	.0566178
U3263	.000957	.0000000	-6.95170	.0843925
U3264	.000999	.0000001	-6.90875	.1111925
U3265	.000994	.0000001	-6.91377	.1073714
U3266	.000969	.0000000	-6.93924	.0917879
U3267	.001	.0000001	-6.90775	.1118607

APPENDIX A TABLE 3
Continued

U3268	.000937	.0000000	-6.97282	.0725676
U3269	.00116	.0000002	-6.75933	.2331691
U3270	.000974	.0000001	-6.93409	.0949329
U3281	.000824	.0000000	-7.10134	.0198447
U3282	.000862	.0000000	-7.05625	.0345796
U3283	.000862	.0000000	-7.05625	.0345796
U3284	.001	.0000001	-6.90775	.1118607
U3285	.000969	.0000000	-6.93924	.0917879
U3286	.00104	.0000001	-6.86853	.1396342
U3287	.000814	.0000000	-7.11355	.0165536
U3288	.000853	.0000000	-7.066751	.0307862
U3289	.000787	.0000000	-7.14728	.0090115
U3290	.000853	.0000000	-7.066751	.0307862
U3301	.000775	.0000000	-7.16264	.0063304
U3302	.000874	.0000000	-7.04243	.0399124
U3303	.000944	.0000000	-6.96538	.076633
U3304	.000951	.0000000	-6.95799	.0807779
U3305	.000891	.0000000	-7.02316	.0479807
U3306	.000853	.0000000	-7.066751	.0307862
U3307	.000814	.0000000	-7.11355	.0165536
U3308	.000824	.0000000	-7.10134	.0198447
U3309	.000862	.0000000	-7.05625	.0345796
U3310	.000783	.0000000	-7.15237	.00807
U3325	.000891	.0000000	-7.02316	.0479807
U3326	.000865	.0000000	-7.05278	.0358837
U3327	.000582	.0000000	-7.44904	.0427782
U3328	.000687	.0000000	-7.28317	.0016781
U3329	.000666	.0000000	-7.31422	.0051854
U3330	.000891	.0000000	-7.02316	.0479807
U3331	.000326	.0000002	-8.02861	.6184282
U3332	.000158	.0000004	-8.752912	.2822278
U3333	.000381	.0000001	-7.87271	.3975303
U3334	.000599	.0000000	-7.420249	.0316975
U3409	.00027	.0000002	-8.21708	.9503861
U3489	.000317	.0000002	-8.05660	.6632436
U3545	.000843	.0000000	-7.07854	.0267871
U3546	.000808	.0000000	-7.12094	.0147046
U3547	.000725	.0000000	-7.22933	.0001657
U3548	.000599	.0000000	-7.420249	.0316975
U3549	.000544	.0000000	-7.51656	.075268
U3550	.000597	.0000000	-7.42359	.0328996
U3551	.000725	.0000000	-7.22933	.0001657
U3552	.000749	.0000000	-7.19677	.0020648
U3553	.000803	.0000000	-7.12715	.0132377
U3554	.000908	.0000000	-7.00426	.0566178
U3555	.000843	.0000000	-7.07854	.0267871
U3556	.000878	.0000000	-7.037864	.0417578
U3557	.000775	.0000000	-7.16264	.0063304
U3558	.000865	.0000000	-7.05278	.0358837
U3559	.000763	.0000000	-7.17825	.0040907
U3560	.000853	.0000000	-7.066751	.0307862
U3561	.000833	.0000000	-7.09047	.0230233

APPENDIX A TABLE 3
Continued

U3562	.00108	.0000001	-6.83079	.1692638
U3563	.000833	.0000000	-7.09047	.0230233
U3564	.000793	.0000000	-7.13968	.0105111
U3585	.000768	.0000000	-7.17172	.0049689
U3586	.000725	.0000000	-7.22933	.0001657
U3587	.000806	.0000000	-7.12342	.0141097
U3588	.000803	.0000000	-7.12715	.0132377
U3589	.000865	.0000000	-7.05278	.0358837
U3590	.000803	.0000000	-7.12715	.0132377
U3591	.000803	.0000000	-7.12715	.0132377
U3592	.000749	.0000000	-7.19677	.0020648
U3593	.000951	.0000000	-6.95799	.0807779
U3594	.000778	.0000000	-7.158784	.0069601
U3595	.000703	.0000000	-7.26015	.0003219
U3596	.000778	.0000000	-7.158784	.0069601
U3597	.00077	.0000000	-7.16912	.0053423
U3598	.000743	.0000000	-7.20481	.0013985
U3599	.000412	.0000001	-7.79448	.3050089
U3600	.000623	.0000000	-7.380964	.0192524
U3601	.000824	.0000000	-7.10134	.0198447
U3602	.000833	.0000000	-7.09047	.0230233
U3603	.000863	.0000000	-7.05509	.0350121
U3604	.000874	.0000000	-7.04243	.0399124
U3632	.000803	.0000000	-7.12715	.0132377
U3633	.000783	.0000000	-7.15237	.00807
U3634	.000689	.0000000	-7.28026	.0014484
U3635	.000854	.0000000	-7.06557	.0311988
U3636	.000723	.0000000	-7.23210	.0001022
U3637	.000674	.0000000	-7.30228	.0036083
U3638	.000674	.0000000	-7.30228	.0036083
U3639	.000749	.0000000	-7.19677	.0020648
U3640	.000712	.0000000	-7.24743	.0000273
U3641	.000712	.0000000	-7.24743	.0000273
U3648	.000787	.0000000	-7.14728	.0090115
U3649	.000722	.0000000	-7.23348	.0000761
U3650	.000642	.0000000	-7.35092	.0118181
U3651	.000717	.0000000	-7.24043	.0000032
U3652	.000717	.0000000	-7.24043	.0000032
U3653	.000756	.0000000	-7.18746	.0029967
U3654	.000764	.0000000	-7.17694	.00426
U3655	.000764	.0000000	-7.17694	.00426
U3656	.000764	.0000000	-7.17694	.00426
U3657	.000764	.0000000	-7.17694	.00426
U3666	.000764	.0000000	-7.17694	.00426
U3667	.000742	.0000000	-7.20616	.0012996
U3668	.000742	.0000000	-7.20616	.0012996
U3669	.00082	.0000000	-7.10620	.0184973
U3670	.000778	.0000000	-7.158784	.0069601
U3671	.00077	.0000000	-7.16912	.0053423
U3672	.000778	.0000000	-7.158784	.0069601
U3673	.000497	.0000001	-7.60692	.133013
U3674	.000385	.0000001	-7.86226	.3844696

APPENDIX A TABLE 3
Continued

U3675	.000343	.0000002	-7.97778	.5410618
U3711	.000666	.0000000	-7.31422	.0051854
U3712	.000692	.0000000	-7.27592	.0011366
U3713	.000679	.0000000	-7.29488	.002775
U3714	.000702	.0000000	-7.26157	.000375
Sum of Column	.117709	.0000055	-1137.02	18.54400
Number of Samples	157			
Average of Column	.0007497		-7.24221	
Standard Deviation		.000187		.3447779
Six STD. DEV.		.0011219		2.0686675
Add Average		.0018716		-5.17354
Convert Log Normal Average to Linear Average				.0007157
Convert 6 x Log Normal (S.D.) to Linear			Answer -	.0056645

Prepared by: D. Thomas Clark 8/13/91

Checked by: K.V. Rodriguez 8/14/91

WHC-SD-CP-ES-144

Rev. 0

APPENDIX B

OTHER REPORTS

Westinghouse Hanford Company WHC-SD-CP-ES-144 REV 0 Internal Memo

From: Process Laboratories and Technology 23100-91-044
Phone: 3-2475 T6-18
Date: July 31, 1991
Subject: STATISTICAL ANALYSIS OF UO_3 PLANT PROCESS CONDENSATE DATA

To: D. C. Hedengren S6-01

cc: J. P. Sloughter T6-07
TLW LB/File

Reference: D. B. Owen. Handbook of Statistical Tables, 1962, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts.

The Statistics Team received data pertaining to the UO_3 Plant process condensate samples. The purposes of the statistical analysis were (1) to determine an upper limit for the uranium composition for future process condensate samples from historical data and (2) to compare this upper limit to the Table II limit which is equivalent to 0.07 g/L uranium concentration (10 CFR 20, Appendix B, Table II Column 2).

The uranium concentration from the process condensate sample results for run number 15 (2/1/88 to 2/5/88) and run number 16 (4/18/89 to 5/16/89) were statistically analyzed. The data are listed in Table 1 (run number 15) and Table 2 (run number 16). The data are illustrated in Figure 1 where index represents the sample numbers in numerical order.

The statistical analyses were completed for (1) run number 15 data, (2) run number 16 data, and (3) run number 15 and run number 16 combined. The data sets were first analyzed using the Kolmogorov-Smirnov test to determine if the data came from a normal distribution. The assumption of normality was rejected for each data set. Since the data are not normally distributed, distribution-free techniques are more appropriate in determining an upper limit for each of the data sets.

A one-sided nonparametric tolerance limit was calculated for each data set. The interpretation of a one-sided tolerance limit is:

> If a sample of n observations is obtained from a population then, with γ % confidence, at least P % of the population lies below the observed maximum value in the sample.

The values of γ and P vary but are functions of the number of observations. The observations are assumed to be a random sample. The following statements can be made for the uranium concentration for each data set

specified. These statements are derived from results on pages 317 and 318 of the reference.

Data Set 1 - run number 15 - number of observations = 82
- maximum value observed = 0.0307 g/L

- With 80% confidence, at least 98% of the population lies below the maximum value observed.
- With 85% confidence, at least 97.5 to 98% of the population lies below the maximum value observed.
- With 90% confidence, at least 97.5% of the population lies below the maximum value observed.
- With 95% confidence, at least 95 to 97.5% of the population lies below the maximum value observed.
- With 98% confidence, at least 95% of the population lies below the maximum value observed.

Data Set 2 - run number 16 - number of observations = 157
- maximum value observed = 0.00116 g/L

- With 80% confidence, at least 98 to 99% of the population lies below the maximum value observed.
- With 85% confidence, at least 98 to 99% of the population lies below the maximum value observed.
- With 90% confidence, at least 98 to 99% of the population lies below the maximum value observed.
- With 95% confidence, at least 98% of the population lies below the maximum value observed.
- With 98% confidence, at least 97.5% of the population lies below the maximum value observed.

Data Set 3 - run numbers 15 and 16 - number of observations = 239
- maximum value observed = 0.0307 g/L

- With 80% confidence, at least 99 to 99.5% of the population lies below the maximum value observed.
- With 85% confidence, at least 99 to 99.5% of the population lies below the maximum value observed.
- With 90% confidence, at least 99% of the population lies below the maximum value observed.

- With 95% confidence, at least 98 to 99% of the population lies below the maximum value observed.

- With 98% confidence, at least 98 to 99% of the population lies below the maximum value observed.

- With 99% confidence, at least 98% of the population lies below the maximum value observed.

It is not possible to compute the probability that the maximum value in a sample is less than the Table II limit of 0.07 g/L for an arbitrary unknown distribution (not the normal distribution). The results from the nonparametric tolerance intervals given above are as close to this type of statement that can be made. The maximum values observed from the two historical data sets are well below the Table II limit.

Probability statements could be made if the samples were from a normal population. However, this assumption is not valid.

If you have any questions, please call.

T. L. Welsh, Senior Statistician
Process Laboratories and Technology

L. Jensen, Principal Statistician
Process Laboratories and Technology

tlw

Table 1 - Run Number 15

Sample Number	Uranium g/L	Sample Number	Uranium g/L	Sample Number	Uranium g/L	Sample Number	Uranium g/L
U2288	0.000184	U2313	0.000478	U2348	0.000787	U2373	0.003110
U2289	0.000183	U2314	0.000487	U2349	0.000719	U2374	0.030700
U2290	0.000214	U2315	0.000278	U2350	0.000634	U2375	0.020100
U2291	0.000232	U2316	0.000568	U2351	0.000894	U2380	0.001170
U2292	0.000228	U2317	0.000374	U2352	0.000313	U2381	0.003490
U2293	0.000134	U2318	0.000691	U2353	0.000772	U2382	0.016900
U2294	0.000177	U2319	0.000244	U2354	0.000708	U2383	0.004470
U2295	0.000226	U2320	0.000484	U2355	0.000700	U2384	0.000732
U2296	0.000312	U2321	0.000378	U2361	0.000767	U2385	0.001540
U2297	0.000223	U2336	0.000778	U2362	0.000760	U2386	0.002040
U2298	0.000165	U2337	0.000857	U2363	0.000696	U2387	0.001070
U2299	0.000184	U2338	0.001200	U2364	0.001220	U2388	0.003130
U2300	0.007480	U2339	0.000681	U2365	0.000749	U2389	0.002450
U2301	0.011400	U2340	0.000742	U2366	0.000930	U2390	0.001230
U2302	0.017400	U2341	0.000708	U2367	0.001190	U2391	0.002500
U2307	0.001030	U2342	0.000530	U2368	0.000634	U2392	0.001620
U2308	0.000866	U2343	0.001300	U2369	0.000800	U2393	0.002410
U2309	0.000450	U2344	0.001020	U2370	0.000936	U2394	0.007030
U2310	0.000449	U2345	0.000937	U2371	0.000429	U2395	0.003260
U2311	0.000449	U2346	0.000800	U2372	0.000805	U2298	0.000005
U2312	0.000487	U2347	0.000813				

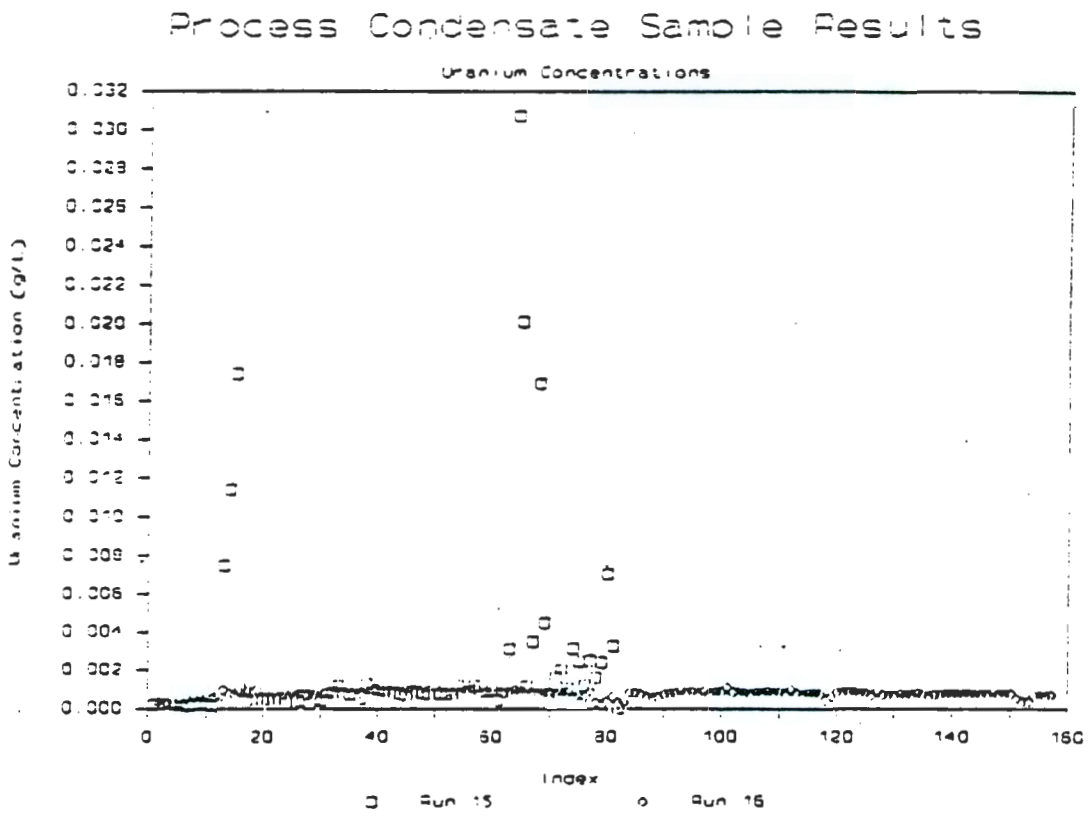
Table 2 - Run Number 16

Sample Number	Uranium g/L	Sample Number	Uranium g/L	Sample Number	Uranium g/L	Sample Number	Uranium g/L
U3153	0.000324	U3209	0.000613	U3229	0.000862	U3299	0.000853
U3168	0.000351	U3210	0.000674	U3261	0.000951	U3301	0.000775
U3169	0.000211	U3211	0.000647	U3262	0.000908	U3302	0.000874
U3170	0.000176	U3212	0.000715	U3263	0.000957	U3303	0.000944
U3171	0.000218	U3213	0.000843	U3264	0.000979	U3304	0.000951
U3172	0.000211	U3214	0.000782	U3265	0.000994	U3305	0.000871
U3173	0.000430	U3215	0.000674	U3266	0.000969	U3306	0.000853
U3174	0.000562	U3216	0.000766	U3267	0.001000	U3307	0.000814
U3175	0.000529	U3217	0.000722	U3268	0.000937	U3308	0.000824
U3176	0.000562	U3218	0.000735	U3269	0.001160	U3309	0.000862
U3177	0.000562	U3219	0.000824	U3270	0.000974	U3310	0.000783
U3200	0.000702	U3220	0.000814	U3281	0.000824	U3325	0.000871
U3201	0.000963	U3221	0.000930	U3282	0.000862	U3326	0.000865
U3202	0.000749	U3222	0.000899	U3283	0.000862	U3327	0.000582
U3203	0.000725	U3223	0.000969	U3284	0.001000	U3328	0.000587
U3204	0.000798	U3224	0.000954	U3285	0.000969	U3329	0.000666
U3205	0.000843	U3225	0.000824	U3286	0.001040	U3330	0.000891
U3206	0.000775	U3226	0.000963	U3287	0.000814	U3331	0.000326
U3207	0.000984	U3227	0.000963	U3288	0.000853	U3332	0.000158
U3208	0.000595	U3228	0.000930	U3289	0.000787	U3333	0.000381

Table 2 (continued) - Run Number 16

Sample Number	Uranium g/L	Sample Number	Uranium g/L	Sample Number	Uranium g/L	Sample Number	Uranium g/L
U3334	0.000599	U3562	0.001080	U3602	0.000833	U3655	0.000764
U3409	0.000270	U3563	0.000833	U3603	0.000863	U3656	0.000764
U3489	0.000317	U3564	0.000793	U3604	0.000874	U3657	0.000764
U3545	0.000843	U3585	0.000768	U3632	0.000803	U3666	0.000764
U3546	0.000808	U3586	0.000725	U3633	0.000783	U3667	0.000742
U3547	0.000725	U3587	0.000806	U3634	0.000699	U3668	0.000742
U3548	0.000599	U3588	0.000803	U3635	0.000854	U3669	0.000820
U3549	0.000544	U3589	0.000865	U3636	0.000723	U3670	0.000778
U3550	0.000597	U3590	0.000803	U3637	0.000674	U3671	0.000770
U3551	0.000725	U3591	0.000803	U3638	0.000674	U3672	0.000778
U3552	0.000749	U3592	0.000749	U3639	0.000749	U3673	0.000497
U3553	0.000803	U3593	0.000951	U3640	0.000712	U3674	0.000385
U3554	0.000908	U3594	0.000778	U3641	0.000712	U3675	0.000343
U3555	0.000843	U3595	0.000703	U3648	0.000787	U3711	0.000665
U3556	0.000878	U3596	0.000778	U3649	0.000722	U3712	0.000692
U3557	0.000775	U3597	0.000778	U3650	0.000642	U3713	0.000679
U3558	0.000865	U3598	0.000743	U3651	0.000717	U3714	0.000702
U3559	0.000763	U3599	0.000412	U3652	0.000717		
U3560	0.000853	U3600	0.000623	U3653	0.000756		
U3561	0.000833	U3601	0.000[illegible]4	U3654	0.000764		

Figure 1


Process Condensate Sample Results
Uranium Concentrations
Uranium Concentration (g/L)
0.032
0.030
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
20
40
60
80
100
120
140
160
Index
Run 15
Run 16

Westinghouse
Hanford Company

Internal
Memo

From: Process Chemistry Laboratories 12221-PCL88-192
Phone: 3-1972 MO-037/200W T6-50
Date: August 15, 1988
Subject: URANIUM SOLIDS FORMATION RESULTING FROM NEUTRALIZATION OF UO_3 PROCESS CONDENSATE

To: J. H. Rasmussen T7-20

cc: L. L. Adams T7-20
D. R. Bratzel T6-50
L. Garrett X3-59
D. C. Hedengren S6-01
S. T. Willett T7-20
RLW File/LB

During the recent operating campaign at the Uranium Oxide Plant (UO_3), special efforts were made to characterize the process condensate stream. Part of this effort involved investigation into formation of uranium-containing solids during the neutralization of process condensate prior to discharge to a crib. Extensive solid formation could lead to plugging of the crib pores, shortening the useful lifetime of the crib.

The investigation showed that the neutralization process used at UO_3 results in precipitation of nearly all of the uranium present in the untreated feed. The total quantity of solids formed is minimal, however, and the solids are similar in size to solids already present in the stream. No significant decrease in the useful life of the crib is expected based on continuing the current neutralization process.

Experimental

Efforts were made to ensure that samples of neutralized and untreated process condensate were taken as "matched pairs," minimizing the variable of differing total uranium concentrations in the streams. The samples were visually inspected for solids. Each sample was thoroughly mixed and aliquots removed for uranium analysis. One aliquot from each sample was analyzed for uranium without further treatment. The pH of the aliquots was determined to assure that the samples were properly identified and that the neutralization had been performed. A second aliquot from each sample was acidified with nitric acid prior to uranium analysis. This should solubilize any uranium solids and allow for determination of total uranium in the stream. A third, large, aliquot was filtered through a 0.45-μ filter. The filtered supernate was analyzed to determine soluble uranium. The filter paper was then leached with strong nitric acid. Analysis of the leachate for uranium allowed determination of the quantity of insoluble uranium in the aliquot. Particle size distribution analysis was also performed on one set of untreated/neutralized samples.

Hanford Operations and Engineering Contractor for the US Department of Energy

Results

Examination of the as-received solutions showed no visible solids present in any samples. Examination of the filter papers, after filtering 200 mL of solution, showed no visible solids collected. The quantity of solids in both untreated and neutralized solutions is very small. The results of the chemical analyses are shown in Table 1. The concentration values for the filtered solids have been adjusted to represent grams per liter of initial solution. The second column in Table 1 (Percent of Untreated) presents the fraction of uranium present in each stream compared to the initial untreated feed uranium concentration. An initial feed concentration was derived by averaging the uranium concentration for the untreated, as-received, and untreated-acidified aliquots for each set of samples.

The results of the neutralized solution analyses are not as self-consistent as the result from the untreated solutions. Truly representative solids/liquid sampling is very difficult to achieve. It appears that aliquots taken from the neutralized solutions did not recover consistent quantities of solids.

Particle size distribution analysis of the first set of samples is summarized in Table 2.

Conclusions

The uranium in untreated UO_3 process condensate is present almost completely as a soluble species. After neutralization, most of the uranium precipitates and is present as a solid. Filtering of the neutralized condensate appears to remove greater than 75% of the uranium in the stream. Neutralization of the condensate does not produce a significant quantity of solids. Precipitation of all of the uranium in solution would produce less than 0.0001% solids by weight. No significant changes in particle size distributions or quantity of solids were seen between untreated and neutralized samples. Based on the samples received, no significant effects on crib life and functioning would be expected from continued use of the condensate neutralization process. If start-up and shut-down conditions vary significantly from these steady state samples, additional investigations on samples from these times would be recommended.

R. L. Weiss, Chemist
Process Chemistry Laboratories

cse

Attachments (2)

TABLE 1 URANIUM ANALYSIS

	URANIUM CONCENTRATION g/l	PERCENT OF UNTREATED
UNTREATED CONDENSATE (ID= R7514) - pH 2.13		
As-received	2.12×10^{-4}	105.
Acid-added	1.95×10^{-4}	95.4
Filtered supernate	1.95×10^{-4}	95.4
Solids	1.77×10^{-6}	0.87
NEUTRALIZED CONDENSATE (ID= R7515) - pH 7.14		
As-received	1.66×10^{-4}	81.2
Acid-added	9.90×10^{-5}	48.4
Filtered supernate	3.21×10^{-5}	15.7
Solids	1.56×10^{-4}	76.3
UNTREATED CONDENSATE (ID= R8165) - pH 2.77		
As-received	1.20×10^{-4}	97.5
Acid-added	1.26×10^{-4}	102.
Filtered supernate	1.16×10^{-4}	94.3
Solids	2.57×10^{-6}	2.09
NEUTRALIZED CONDENSATE (ID= R8166) - pH 7.99		
As-received	5.13×10^{-4}	417.
Acid-added	2.71×10^{-4}	220.
Filtered supernate	2.80×10^{-5}	22.8
Solids	1.57×10^{-4}	128.

TABLE 2 PARTICLE SIZE ANALYSIS

	MEDIAN DIAMETER* µm
UNTREATED CONDENSATE (ID= R75I4) - pH 2.13	
Area of particles	2.52
Volume of particles	4.35
NEUTRALIZED CONDENSATE (ID= R75I5) - pH 7.14	
Area of particles	2.52
Volume of particles	4.23

*Counted over a range of 0.5 - 150 µm