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Subject: CF 57-6-56 (Unclassified)

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ORNL
CENTRAL FILES NUMBER

57-6-56

DATE: June 12, 1957

SUBJECT: Oxygen Concentration in Fuel and Blanket High-Pressure Systems, HRT Run 7

TO: S. E. Beall

FROM: R. Van Winkle and R. R. Wiethaup

COPY NO. 66

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Summary

In Run 7, oxygen was injected into the fuel high-pressure system at about 1075 cc (STP)/min. At the nominal letdown flow of 0.95 gpm, an equilibrium oxygen concentration of 430 ppm should have been maintained if all of the oxygen injected had been dissolved. The observed concentrations of 38 samples reported by the analytical laboratory averaged 70% of the calculated concentrations; during about half of Run 7, from March 9 through March 21. However, the observed concentrations of 11 samples averaged 89% of the calculated concentrations. Measurement of the total volume of gas released from the system upon dumping lends support to conclusions based on the analytical results. It appears that part of the oxygen injected into the fuel feed stream is still undissolved when it reaches the gas separator and is removed in the letdown stream.

In the blanket system, it was attempted to operate with no oxygen injection but FCV-415 (the blanket oxygen flow control valve) leaked ~1100 cc (STP)/min of O₂ into the blanket system for most of the run, resulting in observed oxygen concentrations in the range 300--400 ppm. During this period of leakage through FCV-415 the observed concentrations were about two-thirds of the calculated concentrations. FCV-415 stopped leaking after the shutdown of March 22 and O₂ concentrations in the order of 30 ppm were observed during the last four days of Run 7.

Methods and Results

Observed concentrations were obtained from a measurement of the gas and liquid volumes in samples taken from the high-pressure systems in 60 ml high-pressure sample bombs. Using lines 166 and 167 in the fuel side and lines 266 and 267 in the blanket side, the bomb was installed so as to complete a bypass circuit around the heat exchanger. Estimated flows of ~0.1 gpm for 15 minutes were maintained through the sample bomb during a sampling operation. The solutions were cooled to ~100°C before passing through the bomb.

Any leakage of gas during handling of the bomb or during analysis would of course result in low oxygen concentrations.

Observed concentrations are plotted in Figure I.

On the occasion of two dump tests, the volume of gas in the high-pressure system was measured by observing the change in the off-gas meter reading between the time the dump was initiated and the time that the low-pressure system returned to normal. The results are listed in Table I. Because of the large capacity of the charcoal beds, a small error in pressure measurement could result in a large error in volume of gas, e. g., at 20°C and 15 psia, a pressure decrease of 0.1 psi would result in the release of ~14 liters of oxygen per bed. All three beds were being used in these tests, so a possible error of about 40 liters would not be surprising.

It can be seen, however, that according to these measurements, the analytical results of samples taken shortly before each dump indicated that observed concentrations were at least as great as actually existed.

Calculated concentrations were based on the flow rates of oxygen (as indicated by readings in FR-315 and FR-415 which had been calibrated at 2300 psi) and the flow rates of the letdown streams (as indicated by heat balances on the feed coolers and the purge coolers). Calculated concentrations are plotted in Figure I. Figure II is a plot of the input flow versus calculated concentration at various letdown flows. Comparison of calculated and observed concentrations indicate that on both fuel and blanket sides, only about 70% of the injected oxygen is being dissolved.

Over a 16-day period from March 6 to March 22, the total volume of off-gas from the fuel and blanket system was measured using a wet test meter which was read every two hours. The average flow rate for the period indicated by this measurement was 2.16 l/min (STP). This compares with an average total input flow of 2.10 l/min (STP) that was indicated by FR-315 and FR-415.

The good material balance obtained in this manner lends confidence to the readings of input oxygen flow being indicated by FR-315 and FR-415.

Oxygen is injected into Lines 110 and 210 at the discharge of the feed pumps where it joins the feed streams and passes through approximately 50 ft. of 1/2-in. Sch. 80 pipe (which includes the letdown heat exchanger). The average velocity of liquid in the feed is about 1 ft/sec. If the gas traveled through the piping at the same velocity as the liquid, about 50 sec. would elapse from the time it joined each feed stream until the time it reached the high-pressure circulating streams.

The blanket feed stream is injected into Line 201 at the inlet to the blanket heat exchanger; since the volume of the high-pressure circulating stream is about 460 gallons and the circulating rate is about 200 gpm, it would take about 2.3 minutes to travel through the high-pressure blanket circuit and reach the blanket gas separator. Thus, there is a contact time of about 3 minutes between the gas bubble and the liquid before the gas bubble reaches the gas separator.

On the fuel side the feed stream is injected into Line 100 and almost immediately reaches the gas separator so that the contact time between a gas bubble and the liquid is approximately one minute before the gas bubble reaches the gas separator; yet according to the results, the fraction of injected gas dissolving was approximately equal on both sides. Thus, it appears that time of contact, as extant in the HRT, has little effect on the completeness of the dissolving of oxygen and it would be grasping at straws to relocate the point of injection of the fuel feed stream in order to increase the contact time.

During the last 2 - 1/2 days of Run 7 an attempt was made to increase the oxygen concentration in the fuel system to about 600 ppm by reducing the fuel feed rate from about 0.75 gpm to 0.5 gpm (giving a total letdown rate of ~ 0.67 gpm). The observed concentration gradually increased to 500 ppm during a 24 - hour period in which two samples were taken and then decreased in a fashion typical of the cyclic variations reported during all of Run 7. Two and one-half days did not appear to be a long enough period of time to demonstrate that observed concentrations greater than 500 ppm were attainable using ~ 1070 cc/min input flow and 0.67 gpm letdown flow.

Mass Spectrometer Analyses of Off-Gas

Off-gas samples were taken in glass sample bombs, on two occasions, for analysis by mass spectrometer. The results are listed in Table II. Samples were taken upstream of the charcoal beds from Line 628, and from the discharge line of the charcoal beds. Based on the water analyses reported, and the approximate total pressure of the samples, the dew points of the first pair of samples were 50°F and 55°F and of the second pair 20°F and 5°F. The driest gas came from the discharge of the charcoal bed; however, none of these samples were as dry as the - 10°F dew point specified for the gas leaving the cold trap. Nothing else of significance was learned from these analyses, except perhaps that the experience of the analytical group in mistaking CO for N₂ (because of identical molecular weights) and the postulated reaction of O₂ with stopcock grease to form CO, point up typical pitfalls that lie in the path of experimentalists. If it were not for the uncertainty of the amount of reaction between O₂ and stopcock grease, it might be concluded that possibly 2-1/2% of the oxygen reacted with charcoal.

Conclusions and Recommendations

(1) With the present method of introducing oxygen into the feed streams, an average of 30% of the oxygen injected may be removed as bubbles from the high-pressure systems by the gas separator. The use of orifices at the oxygen injection points as suggested by Hise¹ may result in a larger fraction of oxygen going into solution before reaching the gas separators.

(2) A "thermal" control valve such as was used for FCV-315 appeared to afford much better control of oxygen injection rate than the normal plug and seat valve that was used for FCV-415.

¹Memoranda, E. C. Hise to S. E. Beall, High-Pressure O₂ Injection Line, March 28, 1957 and April 26, 1957.

TABLE I. Oxygen Vented Through Off-gas System Upon Dumping

Date of Dump	3-22-57	3-28-57
<u>Fuel Side</u>		
Water inventory (excl. pressurizers), lb.	769	769
Obs. O ₂ concentration (bomb sample), ppm	310	280
*Calc. volume dissolved O ₂ , liters (STP)	76	69
<u>Blanket Side</u>		
Water inventory (excl. pressurizers), lb.	2896	2896
Obs. O ₂ concentration (bomb sample) ppm	240	35
*Calc. volume dissolved O ₂ , liters (STP)	222	32
*Total calc. dissolved O ₂ , liters (STP)	298	101
Volume of O ₂ released through off-gas meter, l (STP)	252	64
Difference, liters	46	37

*Calculated using water inventory and concentrations reported in bomb samples.

TABLE II. Analysis of Off-gas by Mass Spectrometer

(Composition in mole percent)

Location	<u>Upstream Charcoal Bed</u>			<u>Downstream Bed</u>
Date	3-18	3-18	3-27	3-27
Time	1500	1500	1430	1430
Sample No.	<u>A</u>	<u>B</u>	<u>RM7-422</u>	<u>RM7-423</u>
H ₂ O	1.46	1.21	0.34	0.16
*CO	2.57	2.25	7.67	10.37
O ₂	94.16	94.61	90.86	88.16
A	0.46	0.46	0.56	0.64
CO ₂	1.33	1.45	0.57	0.67
H. C.	0.03	0.02	--	--

*Initially reported as N₂, but upon checking the data it was revealed that similar results were being reported for samples of cylinder O₂; it was postulated that O₂ reacted with stopcock grease to give CO.

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