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TO: I. Spiewak

FROM: P. H. Harley

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INTRODUCTION

In a homogeneous reactor, H_2 (D_2) and O_2 are produced by the radiolytic decomposition of the water which is used as a solvent for the fuel. If high pressure recombination of these gases is feasible, the operation of the reactor would be simplified. These simplifications would be the elimination of the continuous letdown of the radiolytic gases (and some soup) and the elimination of the continuous operation of the feed pump to restore the liquid and recombined gases removed in the letdown operation.

The high pressure recombiner loop was built to determine the following:

1. The efficiency of high pressure catalytic recombination.
2. The avoidability of explosions.
3. The effect of poisoning by I_2 and SO_3 and the contamination by soup.
4. The life of the recombiner with reference to corrosion at the high temperatures.
5. The best catalyst for continuous operation.

SUMMARY

The high pressure recombiner loop has shown 60% to 76% recombination per inch of pellet bed depth with a H_2 concentration of 2 to 4 mole per cent.

The reaction rate at elevated temperature is diffusion-controlled as shown by work at low pressure. The theoretical mass transfer coefficients, K_g , were in the range of 60×10^{-3} to 16.5×10^{-3} pound moles per second per square foot in the high pressure recombiner. The experimental K_g 's were 40 to 60% of the theoretical value.

Stainless steel wire mesh has proven to be superior to the activated alumina pellets as a support for the platinized platinum catalyst. However, the volume of bed per unit of surface area of the catalyst was increased by a factor of three when the wire mesh was used. The pressure drop through the wire mesh was only half the pressure drop through the pellets.

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There have been only a limited number of runs made since the loop was re-designed to pass steam diluent through the electrolytic cells. These tests indicate that explosions can be prevented but this needs further verification by long term operation.

Stress corrosion cracking has been a serious problem in the high pressure recombiner loop and a suitable material of construction will have to be found. 304 stainless steel and 347 stainless steel have shown stress corrosion cracking with Cl^- content of the liquid from 100 to < 1 ppm and do not appear to be satisfactory materials for construction. A caustic environment was always present.

Titanium and zircaloy-2 samples placed in the loop at the recombiner beds and at the electrolytic cell have been examined metallographically and do not appear to be satisfactory materials for recombiner construction.

The future program will be to study the stress corrosion problem and find a suitable construction material. Then some long runs can be made to determine the long term operating characteristics of the loop. Finally, some poisoning tests can be made.

DISCUSSION

The high pressure recombiner loop, Figure 1, consisted of three catalyst beds, a partial condenser, condensate tank, and a boiler which pressurized the loop and furnished steam diluent. The components were connected into a closed loop. A stoichiometric mixture of H_2 and O_2 were supplied by two high pressure electrolytic cells which had a capacity of one standard cubic foot of gas per minute. Steam and argon diluent were used to keep the H_2 and O_2 below an explosive mixture. The argon was used primarily to prevent cavitation of the circulating pump.

Forced circulation of the gases were maintained by a water jet ejector operated by a 5 gpm, ORNL, canned rotor pump which circulated water from the boiler through the ejector and back to the boiler. The gas flow was controlled from 0 to 1.3 cfm by throttling the water flow from the pump. The gases were ejected into the boiler, and passed through the recombiner beds. The flow of air, the condenser coolant,

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Fig 1 High Pressure Recombiner Loop

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was controlled by the loop temperature at the condenser outlet. This allowed water, equivalent to the amount recombined, to be condensed and returned to the condensate tank without condensing the diluent steam. The diluent was returned to the ejector inlet to complete the cycle. From the condensate tank, water flowed by gravity to the generating cells to replace the water which was removed by electrolysis to H_2 and O_2 .

The instrumentation consisted of an orifice and d/p cell to measure the total gas flow to the recombiner; a boiler temperature controller which determined the loop saturation temperature and steam partial pressure; a loop pressure recorder and two d/p cells to measure the electrolytic cell and boiler liquid levels. Thermocouples were located at the orifice, following each recombiner bed, inlet and outlet of the condenser and at the electrolytic cells

The H_2 and O_2 flows were computed from ammeter readings of the DC current supplied to the electrolytic cells.

Safety features consisted of an interlock system on all control variables, which would automatically shut the loop down if the variables were outside of specified limits. Rupture discs were located at both generating cells, in the piping between the cells and the loop and at the boiler. The panel board and controls were located outside of the room where the loop was located.

OPERATION

The operating history of the loop is shown in Table 1.

CORROSION

Metallographic examinations have been made on cracks found in seven out of eight 304 stainless steel ring joint flanges at the catalyst beds and in the wall of the partial condenser. All the cracks were apparently caused by stress-corrosion at the time of failure. The loop had been in operation for 950 hours with several startups and shutdowns.

The corrosion was blamed on the high Cl^- concentration with O_2 present in the superheated steam. 100 ppm of chlorides were found in the KOH used in the electrolytic cells.

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TABLE 1 - OPERATING HISTORY OF THE HIGH PRESSURE RECOMBINER LOOP

<u>From</u>	<u>To</u>	<u>Operating Hours</u>	<u>Loop Pressure psi</u>	<u>Description of Operation</u>
10/19/54	11/6/54	136	100-1000	This period was used to correct faults of the system. Superheaters were added to dry the steam. The condenser was modified for better control. The catalyst was damaged by flask-backs twice.
11/7/54	11/18/54	184	1000	Some good runs were made. The catalyst was damaged by one flashback. The final shutdown was caused by an explosion in the H ₂ - O ₂ generating system.
11/18/54	12/24/54			The loop was down for repair.
12/26/54	3/18/55	633	500	Runs were made to check the following catalysts: (1) Pt on copper wire; (2) Pt on stainless steel mesh from Baker Co.; (3) Pt on stainless steel mesh from Catalytic Co.; (4) Pd on stainless steel mesh; (5) Pt on alumina pellets soaked in UO ₂ SO ₄ solution. The loop was shut down by explosions four times.
3/19/55	4/18/55			The loop was rebuilt to prevent explosions by passing steam through electrolytic cells.
4/18/55	7/27/55	102	500	Several short runs were made which were terminated by leaks. All catalyst cells were replaced. The old cells had been damaged by stress corrosion. The caustic entrainment was very bad.
7/28/55	1/16/56			The loop was rebuilt to lower entrainment.
1/16/56	2/21/56	324	500	Ba(OH) ₂ was used instead of KOH in electrolytic cells to lower Cl ⁻ and prevent stress corrosion. Some trouble was had with the ORNL pump and throttling valve. Ba(OH) ₂ caused general corrosion of mild steel piping in generating cells.
2/22/56	3/14/56			The loop was down while Cl ⁻ free KOH was being prepared.
3/15/56	4/23/56	200	500	Runs were made using Cl ⁻ free KOH and with Ti and Zircaloy-2 samples in the loop. The loop was shut down three times by leaks.
10/19/54	4/23/56	1613		Total operating time.

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$\text{Ba}(\text{OH})_2$ was tried as a replacement for the KOH but proved to be unsatisfactory because it had too low a solubility and also increased general corrosion in the electrolytic cells. Chloride free KOH was made from metallic potassium and distilled water using potassium-mercury amalgam as an intermediate.

In the last 200 hours of operation, after rebuilding the loop with 347 stainless steel and after changing to the Cl^- free KOH, two cracks developed and were examined. One of the cracks was caused by stress corrosion and originated in a weld with poor penetration. The cause of the other crack, which was intergranular, has not been determined.

It is planned to rebuild the part of the loop where stress corrosion has occurred out of 309 stainless steel which has better stress corrosion properties. Also, Incoloy will be examined as a construction material.

The structure of zircaloy-2 and titanium samples placed in the loop was affected by the adsorption of H_2 and they appear to be unsatisfactory materials¹. This test will be repeated in the next run.

EXPLOSIONS

During an early run, the loop was shut down with unrecombined H_2 and O_2 in the system. On the next startup, a flashback occurred which pulverized the platinized alumina pellets and spread the catalyst throughout the loop. Following this, four runs were terminated by explosions. It was theorized that some of the platinum powder had been deposited where the dry $\text{H}_2 - \text{O}_2$ mixture entered the main loop. When this catalyst became dry, it ignited the entering gases.

The loop was redesigned so that steam diluent was passed through the electrolytic cells, Figure 2. This was quite effective in preventing explosions. However, the new design presented a problem of entrainment.

The caustic was entrained by the steam in the electrolytic cells and scrubbed out in the boiler. The electrolytic cells were gradually depleted of KOH and the generation of H_2 and O_2 would stop.

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Fig.2 High Pressure Recombiner Loop - Modification 1

The second loop modification, Figure 3, was made to lower the entrainment and furnish a recycle stream which returned entrained KOH to the generating cells.

CATALYST STUDIES

Good catalytic efficiency data was obtained using platinized alumina pellets. In the first one inch bed of pellets, 60 to 70% of the H_2 and O_2 was recombined. The three one inch beds were sufficient to give close to 100% recombination. In later runs, the alumina pellets in the first bed were replaced by platinized stainless steel wire mesh. The same total surface area was maintained. This increased the volume of the bed by a factor of three. The wire mesh catalyst bed had the same efficiency range, i.e., 60 - 70% and was stronger mechanically. The wire mesh was not damaged by flashbacks. The results of several runs are shown in Table 2.

One run using excess O_2 gave an efficiency of 86% for the first bed.

The method of calculation is shown in Appendix A.

From equations given by I. Spiewak and R. E. Aven, "Design of ISHR Catalytic Recombiner," CF-53-6-162, the mass transfer coefficient, K_g , was calculated and compared to the experimental K_g for 13 runs. The results are tabulated in Table 3. There was too much scatter in the results and too many variables in the different runs to make general conclusions.

The results indicate that the reaction rates are about 40 - 60% of those predicted from diffusion of the gases to the catalyst surface. Behavior is similar to that observed in low pressure tests².

Diffusion in packed beds has been studied by many investigators and the mass transfer coefficient has been defined by the empirical equations³.

$$K_g = \frac{j_D G}{M_n (\mu/\rho_D)^{2/3}}$$

$$j_D = 0.99 \frac{D_p G}{\mu} \quad 0.41$$

K_g = mass transfer coefficient, lb moles/hr, ft², mole

G = mass flow rate, lb/hr, ft²

M_n = mean molecular weight, lb/lb mole

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Fig 3 High Pressure Recombiner Loop Modification 2

TABLE 2 - CATALYST RECOMBINATION

<u>Run</u>	<u>Flow cfm</u>	<u>mol % H₂</u>	<u>Catalyst* Bed I</u>	<u>Pressure psia</u>	<u>Bed I</u>	<u>Bed I plus II</u>
A	1.30	2.02	Wire mesh	520	70.0	92.0
B	.60	2.68	Wire mesh	515	62.8	80.7
C	.80	2.68	Pellets	520	67.0	89.5
D	.76	2.80	Pellets	520	70.7	90.8
E	.545	3.25	Pellets	515	60.0	83.8
F	.60	3.86	Pellets	540	65.0	87.0
G	.96	2.12	Wire mesh	525	68.0	84.2
H	.96	2.02	Wire mesh	530	68.1	85.7
I	.91	2.01	Wire mesh	545	64.2	84.3
J	.545	4.36	Pellets	1000	67.5	93.0
K	.540	3.80	Pellets	1000	63.5	92.3
L	.55	4.28	Pellets	1000	63.0	91.8
M**	.56	4.20	Pellets	1000	86	99.0

* Beds II and III contained pellets in all runs.

** Includes 400% excess O₂.

TABLE 3 - MASS TRANSFER COEFFICIENTS

Run	Calculated Kg x 10 ³ lb m/hr, ft ² mf	Experimental Kg x 10 ³ lb m/hr, ft ² mf	$\frac{\text{Kg(Exp.)}}{\text{Kg(Calc.)}}$	Cat.	T(Bed) °F	Pres. psia	Flow cfm
A	16.5	8.78	.535	Wire mesh	724	520	1.30
B	9.68	3.54	.355	Wire mesh	790	515	0.60
C	10.16	6.62	.650	Pellets	716	520	0.80
D	6.68	4.98	.745	Pellets	800	520	0.670
E	6.00	2.77	.462	Pellets	805	515	0.545
F	6.88	3.75	.545	Pellets	894	540	0.600
G	9.37	6.25	.667	Wire mesh	763	525	0.96
H	9.47	6.35	.671	Wire mesh	758	530	0.96
I	9.11	5.65	.620	Wire mesh	724	545	0.91
J	12.87	8.20	.637	Pellets	726	1000	.545
K	13.20	7.33	.555	Pellets	678	1000	.540
L	13.08	7.31	.559	Pellets	705	1000	.550
M	24.10*	14.78	.613	Pellets	795	1000	.560

* Included 400% excess O₂.

μ = viscosity, lb mass/ft, hour

ρ = density, lb/ft³

D = diffusivity, ft²/hr

D_p = equivalent spherical diameter of one pellet, ft²

The term $D_p G/\mu$ in the " j_s " factor is a modified Reynolds number based on the equivalent spherical diameter, D_p , of the pellets when the void fraction is between 40% and 60%.

No generalized work has been done with wire mesh packing to define K_g . In this report, the packed bed theory was used in wire mesh calculations, substituting $G/\mu S$ for the Reynolds number. The validity of this method is very doubtful but the results were reasonable, Table 3.

The generalized equation suggested by Gamson⁴

$$\frac{K_g}{G/Mn} \left[\frac{\mu}{\rho D_p} \right]_f^{2/3} = 1.46 \left(\frac{D_p G}{\phi(1-V)} \right)^{-0.41} (1-V)^{0.2}$$

was tried for both wire mesh and pellets but the resulting K_g values did not appear consistent with the experimental results. The three terms in question were the constant, 1.46, the term $1 - V$ (V = void fraction) and the calculated D_p for the wire mesh.

While trying to find a mechanically-stronger catalyst than the platinized alumina pellets, three different wire mesh-based catalysts were tested. Copper wire plated with platinum by Y-12 had too low an efficiency. Platinized wire mesh prepared by Baker Chemical Co. recombined the H_2 and O_2 satisfactorily but 50% of the platinum was lost during 16 hours of operation.

Wire mesh platinized by Catalytic Combustion Corporation has been used in the loop for 300 hours at 500 psi and tested at atmospheric pressure for 1000 hours without damaging the catalyst. 400 Starts and stops were made with no ill effects. These starts were made at atmospheric pressure in air and amounted to minor flash-backs.

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Palladium was tested on stainless steel wire mesh as a replacement for platinum but an oxide film formed that stopped the recombination so palladium testing was abandoned.

A batch of platinum coated alumina pellets was heated to 1500°C for several hours. This hardened the pellets but ruined the catalytic action of the platinum.

Platinized alumina pellets which had been soaked 72 hours in UO_2SO_4 solution gave good recombination rates. The UO_2SO_4 solution was probably washed off during the startup of the loop.

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APPENDIX A - SAMPLE CALCULATIONS OF CATALYST EFFICIENCY

The efficiency calculations are based on trial-and-error treatment of the measured temperatures and total pressure, assuming a flow rate as a first approximation. It is assumed that recombination is complete. If the recombination were not complete, the system pressure would not remain constant.

The data used were:

Pressure	520 psia	Bed I	Temp. 678°F
Saturation temperature	442°F	Bed II	Temp. 712°F
Superheat temperature	482°F	Bed III	Temp. 705°F
Amps. to generating cell	2,040		
Orifice pressure drop	40 in. H ₂ O		
Assumed flow rate	0.8 cfm		

To calculate the gas composition given in Table 4, the H₂ and O₂ generated were figured from Faraday's Law assuming an efficiency of 98%. 2,040 amps. will generate 0.491 scfm of H₂ and 0.245 scfm of O₂. Dividing each volume by 359 (ft³/lb mole) will give the flow of H₂ and O₂ in pound moles per minute. The H₂ and O₂ densities were determined by dividing the flow (lb m/min) by the assumed flow rate (cu. ft/min) and the molecular weight. The partial pressures were calculated from the perfect gas law.

The steam partial pressure was obtained from the steam tables using the saturation temperature. The steam density was taken from tables for superheated steam using the saturation pressure and superheated temperature of the loop. Then the steam flow rate (moles/min) was calculated from the steam density and the assumed flow rate (0.8 cfm).

The argon partial pressure was obtained by the difference of the sum of the H₂, O₂ and steam partial pressures from the total pressure. The argon density was calculated by the equation:

$$\rho = \frac{M_n \times P}{1.315 \times T} \quad (1)$$

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ρ - density lb/ft³

ρ - argon partial pressure lb/ft²

T - absolute temperature, °C.

M_w - molecular weight

The argon flow rate (moles/min) was then calculated by converging the density of moles per cubic foot and multiplying by the assumed flow rate.

TABLE 4 - VAPOR COMPOSITION

Element	Part. Press. psi	Density lb/ft ³	lb moles/min
H ₂	16.5	.0034	.00138
O ₂	8.25	.0268	.00069
H ₂ O	390	.778	.0346
A	<u>105.25</u>	<u>.415</u>	<u>.00828</u>
	520	1.2232	

To confirm the first assumed flow, a flow was calculated from the gas density in Table 4 and orifice pressure drop. The flow in this example was calculated with a Foxboro flow slide rule which gave 15.2 cfm at 14.4 psia and 60°F. This flow, corrected for temperature and pressure, was 0.79 cfm compared to the assumed flow of 0.80 cfm.

If the calculated flow varied from the assumed flow by more than 2%, a new flow was assumed and the vapor composition was recalculated.

To obtain efficiency of catalyst, the temperature of the product gases is calculated and plotted against per cent recombination for 1%, 50% and 100%.

The orifice temperature is the base temperature, i.e., 482°F.

H_r for H₂ + 1/2 O₂ → H₂O is 105,700 Btu/lb mole at 482°F.

Basis: 1 minute

H_r = 105,700 x .00069 = 145.8 Btu for 100% rec.

H_r = $\frac{105,700}{2}$ x .00069 = 72.9 Btu for 50% rec.

Neglecting the unrecombined H_2 and O_2 , the enthalpy, H_T , of the products was the summation of

$$H_{H_2O} = \text{moles} \times M_w \times \Delta h \text{ (steam tables) from 482 to temp. of products } (T_p)$$

$$H_A = \text{moles} \times cp \times \Delta T \text{ from 482 to } T_p$$

Different values were assumed for the temperature of the products until the enthalpy of the products equaled the heat of reaction H_R .

For 100% recombination, assume $T_p = 840^\circ F$

$$H_{H_2O} = .036 \times 18 \times 220 = 130.0$$

$$H_A = .00866 \times 4.97 \times 358 = 15.4$$

$$H_T = 145.4 \approx 145.8$$

$$100\% \text{ recombination } 840^\circ F = T_p$$

$$\text{Repeat process if } H_T (T_p) = H_R$$

The calculation is next made for 50% recombination.

Assume $T_p = 660^\circ F$

$$H_{H_2O} = .0353 \times 18 \times 103 = 65.4$$

$$H_A = .0866 \times 4.97 \times 179 = 7.6$$

$$H_T = 73.0 \approx 72.9$$

Assuming 100% recombination $T_p = T_{\text{Bed III}} = 840$ if there is no heat losses.

The ΔT for heat loss of all three beds = $840 - 705 = 135^\circ F$

$$\Delta T/\text{Bed} = \frac{135}{3} = 45^\circ F$$

$$\text{Corrected temperatures Bed I} = 678 + 45 = 723$$

$$\text{Bed II} = 712 + 2(45) = 802$$

$$\text{Bed III} = 705 + 3(45) = 840$$

From graph of bed temperature vs. % H_2 recombined (Fig. 4)

$$\text{Bed I efficiency} = 67.0\%$$

$$\text{Bed I and II efficiency} = 89.5\%$$

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Figure 4 Bed Temp Vs % H₂ Recombined

○ Calculated Temperature
X Corrected Bed Temperatures

Pressure 520 p.m.a.

Temperature 442°F SURCO HEATED TO 482°F

Flow 0.20 FM

H₂ 0.00138 Mole/liter

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APPENDIX B - SAMPLE CALCULATION OF MASS TRANSFER COEFFICIENT

The mass transfer coefficient, K_g , was calculated by the method described in CF-53-6-162⁵. Equations (1) and (2) were the basic equations used,

$$K_g = \frac{j_D G}{Mm \left(\frac{\mu}{D} \right)^{2/3}} \quad (1)$$

$$j_D = 0.99 (N_{Re})^{-0.41} \quad (2)$$

$$N_{Re} = \frac{C \rho V_o}{\mu S} \quad \text{for wire mesh}$$

$$N_{Re} = \frac{D_p V_o \rho}{\mu} \quad \text{for alumina pellets}$$

D_{om} = mean diffusivity of O_2 through film to the catalyst, ft^2/hr

D_p = equivalent spherical diameter of the pellet, ft

G = mass flow rate $lb/hr, ft^2$

Mm = mean molecular weight of the gas $lb/mole$

S = surface area per volume of bed ft^2/ft^3

V_o = velocity, ft/hr

ρ = density, lb/ft^3

μ = viscosity, $lb \text{ mass}/ft-hr$

Calculation data

Pressure 520 psia   Moles/min   A 0.00866

Temp. (orifice) = 482°F   Moles/min H_2O 0.0376

Temp. bed 678°F   Total flow 0.8 cfm

Catalyst: Platinized alumina pellets

Ave. diameter   0.129"

Ave. length   .148"

Length of bed   1"

Diameter of bed   0.957"

226 pellets per bed

$$\text{Pellet area} = \frac{\pi (.148) (.129) + .5 \pi (.129)^2}{144} = 5.98 \times 10^{-4} \text{ ft}^2 \text{ per pellet}$$

$$D_p = \sqrt{\frac{a}{\pi}} = \sqrt{\frac{5.98 \times 10^{-4}}{\pi}} = 1.38 \times 10^{-2} \text{ ft.}$$

$$D_{om} = n_1 D_{(O-H_2O)} + n_2 D_{(O-A)} \text{ ft}^2/\text{sec.}$$

$$D_{O-H_2O} = 2.6 \times 10^5 \text{ ft}^2/\text{sec.} \quad (\text{Ref. p 64-65 of ORNL 1796})$$

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To estimate argon-oxygen D from oxygen-water D:

$$D_{O-A} \approx D_{O-H_2O} \left(\frac{\sqrt{\frac{1}{M_{wO_2}}} \sqrt{\frac{1}{M_{wA}}}}{\sqrt{\frac{1}{M_{wO_2}}} \sqrt{\frac{1}{M_{wH_2O}}}} \right) = 3.7 \times 10^{-5} \times \left[\frac{.237}{.294} \right]$$

$$D_{O-A} = 2.98 \times 10^{-5} \text{ ft}^2/\text{hr}$$

$$\text{Mole fraction } H_2O = .813$$

$$A = .187 \text{ from Appendix A}$$

$$D_{om} = .813 (3.7 \times 10^{-5}) + .187 (2.98 \times 10^{-5}) = 2.51 \times 10^{-5} \text{ ft}^2/\text{sec.}$$

$$\rho (A+H_2O) = 0.778 + .415 = 1.193 \text{ lb/ft}^3$$

$$\text{Mass flow} = 1.193 \times .8 = .956 \text{ lb/min}$$

$$M_m = .813 \times 18 + .187 \times 40 = 22.15$$

$$V_o = \frac{.800 \text{ cfm}}{.00499 \times 60} = 2.67 \text{ ft/sec}$$

$$\mu = .034 (.187) + .0271 (.813) = .02845 \text{ cp}$$

$$\mu = 0.0688 \text{ lb/ft-hr.}$$

$$N_{Re} = \frac{1.38 \times 10^{-2} \times 2.67 \times 1.193 \times 3600}{.0688} = 2300$$

$$J_D = .99 (2300)^{-0.41} = .0414$$

$$\left(\frac{\mu}{\rho D} \right)^{2/3} = \left(\frac{.0688}{3600} \times \frac{1}{1.193} \times \frac{1}{2.51 \times 10^{-5}} \right)^{2/3} = 0.741$$

$$K_g = \frac{.0414 \times .956}{22.15 \times .587 \times .00499 \times 60} = 1.016 \times 10^{-2} \text{ lb moles/hr, ft}^2, \text{ mole fraction}$$

$$K_g (\text{exp}) = \frac{\ln \left(\frac{P_{Ao}}{P_a} \right)}{M_m \text{ SL}} \times G \quad (5)$$

$$= \frac{\ln (3.33) \times .956}{22.15 \times 27.33 \times .00495 \times 60} = 8.05 \times 10^{-3} \text{ lb moles/hr, ft}^2, \text{ mole fraction}$$

$$P_{Ao} = P_p \text{ O}_2 \text{ entering bed}$$

$$P_a = P_p \text{ O}_2 \text{ leaving bed}$$

$$L = \text{length of bed in feet}$$

$$\text{SL} = \frac{226 \text{ pellets}}{\text{bed}} \times \frac{5.984 \times 10^{-4} \text{ ft}^2/\text{pellet}}{0.00046 \text{ ft}^3/\text{bed}} \times \frac{1 \text{ ft.}}{12} = 27.33 \frac{\text{ft}^2}{\text{ft}^3} \times \text{ft.}$$

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The only change in calculating K_g for wire mesh was in the Reynolds Number, N_{Re} by substituting $1/S$ for D_p .

As pointed out in the report, page 11, $1/S$ is not equivalent to D_p in the Reynolds numbers so the resultant K_g 's although in the same range are not directly comparable.

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