THE BABCOCK & WILCOX COMPANY
POWER GENERATION GROUP

PRELIMINARY

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To
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From
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THE-79-195

BDS 663.3

Cust.
TMI-2

File No. or Ref.

Subj.
CORE FLOW DISTRIBUTION FOR ONE PUMP AND TWO PUMP OPERATION

Date
APRIL 10, 1979

This letter to cover one customer and one subject only.

ONE OF THE IMPORTANT CONSIDERATIONS IN ANALYZING THE TMI-2 CORE BLOCKAGE IMPACT ON CORE COOLING IS THE FLOW DISTRIBUTION IN THE CORE. A DETERMINATION OF CORE INLET FLOW DISTRIBUTION FOR ONE PUMP OPERATION WITHOUT BLOCKAGE WAS BASED ON A REVIEW OF THE VESSEL MODEL FLOW TEST (VMFT) DATA AND ENGINEERING JUDGEMENT AS FOLLOWS:

THE TRANSFER OF MASS CAN BE MODELED SIMILAR TO ELECTRIC CIRCUITRY. THE FLOW PATHS CAN BE REPRESENTED BY A SYSTEM OF RESISTANCES AND THE FLOW WILL SELECT THE FLOW PATH IN SUCH A WAY TO EQUALIZE THE PRESSURE DROP ACROSS THE SYSTEM. THUS, FLOW HAS A "LOOK AHEAD" CAPABILITY THAT TENDS TO EQUALIZE THE POTENTIAL (ΔP) ACROSS A SYSTEM OF RESISTANCE. THE FLOW CHANNELS THROUGH THE CORE CAN BE VIEWED AS A SYSTEM OF RESISTANCES. BASED ON THIS PRINCIPLE, ASSUMING THAT RATE OF CHANGE OF MOMENTUM FROM COLD LEG INLET TO HOT LEG OUTLET IS THE SAME, AND AN INSPECTION OF THE VMFT INLET FLOW FACTORS CAN BE USED TO IDENTIFY THE FLOW DISTRIBUTION AT THE CORE INLET FOR ONE PUMP OPERATION.

FIGURE 1 ILLUSTRATES THE CORE INLET FLOW FACTORS FOR 4 PUMP OPERATION FOR THE 177 FA PLANT. SUMMARIZED ON FIGURE 1 ARE THE AVERAGE FLOW FACTORS FOR EACH QUADRANT. THE OUTLET PIPE IS LOCATED BETWEEN QUADRANTS A1 AND A2

AND BETWEEN B1 AND B2. THUS, WITH BOTH LOOPS OPERATING THE RESISTANCES ACROSS THE CORE FOR EACH QUADRANT WOULD BE EXPECTED TO BE ABOUT THE SAME. FIGURE 1 ILLUSTRATES A SLIGHT BIAS TOWARDS QUADRANTS A1, A2, AND B1. THIS BIAS IS PROBABLY DUE TO FABRICATION TOLERANCES.

FIGURE 2 ILLUSTRATES THE CORE INLET FLOW FACTORS FOR TWO PUMP OPERATION. NOTE THAT THE OPERATING PUMPS A1 AND B2 ARE ARRANGED IN OPPOSITE QUADRANTS. THE SUMMARY FLOW FACTOR FOR EACH QUADRANT AGAIN ILLUSTRATES A RELATIVELY UNIFORM FLOW FOR THE QUADRANTS WITH A SLIGHT BIAS TOWARDS THE QUADRANTS CONTAINING THE OPERATING PUMPS. NOTE THAT THE OPERATING PUMP COMBINATION IS A TWO LOOP OPERATION. THEREFORE, THE RESISTANCE ACROSS EACH QUADRANT SHOULD BE ABOUT THE SAME WITH THE RESISTANCES HIGHER FOR THOSE CHANNELS FARTHEST FROM THE PUMP AND FARTHEST FROM THE OUTLET PIPING. HOWEVER, THE MOMENTUM OF THE FLOW DISCHARGED INTO THE CORE MAY BE SUFFICIENT TO OVERCOME LATERAL CORE RESISTANCES IN THE LOWER PLENUM. THIS IS ILLUSTRATED IN FIGURE 3.

FIGURE 3 SHOWS THE CORE INLET FLOW DISTRIBUTION FOR A TWO PUMP OPERATION A1, AND B1. IN THIS INSTANCE THE TWO PUMPS ARE NOT OPPOSING. NOTE THAT BOTH LOOPS ARE OPERATING. THUS, THE RESISTANCE ACROSS EACH QUADRANT ARE ABOUT THE SAME. HOWEVER, AS MENTIONED PREVIOUSLY, THE LATERAL MOMENTUM OF THE FLOW DISCHARGED INTO THE LOWER PLENUM FORCES FLOW TO THE ADJACENT QUADRANT WITH A2 AND B2 HIGHER IN INLET FLOW THAN A1 AND B1 CONTAINING THE PUMPS.

FIGURE 4 ILLUSTRATES THE CORE INLET FLOW DISTRIBUTION FOR A 1 LOOP 2 PUMP OPERATION (A1 AND A2). THE INLET FLOW FACTORS SHOW A BIAS WITH QUADRANTS A1 AND A2 HIGHER IN FLOW. THIS SUGGESTS THAT THE RESISTANCE OF THE CORE QUADRANTS FOR THE CLOSED LOOP IS HIGH OVERCOMING THE LATERAL MOMENTUM OF THE

DISCHARGED FLUID AND RECEIVES LESS FLOW. FIGURE 4 SHOWS THAT ABOUT 4% MORE FLOW ENTERS LOOP A CORE QUADRANTS THAN ENTERS LOOP B QUADRANTS. WHEN VIEWED WITH THE INFORMATION OF FIGURE 3, IT IS BELIEVED THAT THE QUADRANTS B1 AND B2 HAVE A HIGHER RESISTANCE OVER THE COMPLETE LENGTH OF THE CORE. THIS OCCURS DUE TO THE "LOOK AHEAD" CAPABILITY OF THE COOLANT WHICH SEES THE CLOSED LOOP AND THE LATERAL RESISTANCE BETWEEN QUADRANTS B1 AND B2 AND THE OUTLET PIPING OF LOOP A. THEREFORE, IT IS CONCLUDED THAT A COMBINATION OF FIGURE 3 AND FIGURE 4 IS THE MOST REPRESENTATIVE OF ONE PUMP OPERATION. FROM FIGURE 3, THE QUADRANT ADJACENT AND IN THE SAME LOOP WILL BE BIASED ABOUT (1.5 - 2.5%) HIGH IN CORE INLET FLOW. THE FLOW FACTORS SHOWN IN FIGURE 5 ARE RECOMMENDED FOR ANALYZING TMI-2 ONE PUMP CORE INLET FLOW CONDITION.

RMH/FFA

CC: F.E. UNIT MGRS.
J.S. TULENKO
CORE HOT SPOT TASK FORCE

Note °

Fig 1

RC TRESS

SPND STRING NUMBERS AND LOCATIONS — 177 FA CORE

K STRING NO.

A_2 Ave = 1.0103

A_1 Ave = 1.0116

B_2 Ave = 1.0059

B_1 Ave = .9724

				.937	.890	.943	.967	.970					
		.963	1.05	.983	.967 31	.983 20	.977	.993	.960	.960			
	.953	1.017	1.010	.977 32	1.04	.983	.997 29	1.073 28	1.000	1.010	.987 52		
.980	1.020	.990	1.120 33	1.027	1.017	1.040	1.037	1.030 27	1.000	1.080	1.013	.987 31	
.987	1.010	1.070 34	1.097	1.080	1.040 7	1.027	1.070 5	1.037	1.070 26	.987	.993	1.043	
.910	.940	1.033 35	1.067	1.140	1.043	1.000 6	1.023 4	.970	1.140	.990	1.043 24	1.000 22	1.023
.950	.990 36	.957	1.083	.973 9	1.037 8	1.017	1.007	1.017 3	1.093	1.117 25	1.010	.993 12	.973
.893 37	.963	1.120	.930	1.057 10	1.077	1.083	1.107 1	1.020 2	1.053	.920	.987	.980 21	.970
.917	.963	1.000	1.120	1.143 11	1.000	1.097	.997	1.033	1.037	1.083 19	1.033 20	.923	1.017
.883	.940 38	.980 39	1.063	1.040	1.070 12	1.027	1.070	.977	.957	1.000 18	.983	.967 50	1.007
	.940	.977 40	1.110	1.170	1.057	1.073 13	1.010	.950 16	1.037 17	.930	1.000	1.000	.960 49
	.900	.957	.993 41	1.117	1.110	1.033	.947 14	.973 15	1.000	.970	.970	.933	.900
		.977	.930	.980 42	.913 43	1.050	1.070	1.017	.923 47	.933	.893 48	.947	
			.900	.990	.940 44	.957	.980	.970	.940	.937	.907		
					.910	.957 45	.910 46	.920	.897				

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

DRAWN

CKT

JOB NO.

RC PRESS

Fig. 2

SPND STRING NUMBERS AND LOCATIONS – 177 FA CORE

K	STRING NO.

				.920	.907	.970	1.060	1.070						
			.933	1.020	.973	.907 (31)	.987 (30)	.993	1.007	1.020	1.037			
		.960	.987	.980	.943 (32)	1.040	1.003	1.030 (24)	1.033 (23)	1.043	1.080	1.050 (22)		
	.940	.997	.930	1.097 (33)	1.023	.997	1.047	1.037	1.047 (27)	.957	1.170	1.093	.987 (31)	
	.947	.983	1.043 (34)	1.063	1.067	1.067 (7)	1.040	1.083 (5)	1.017	1.107 (26)	.990	1.023	1.037	
923	.927	1.003 (35)	1.050	1.097	1.067	.983 (6)	.973 (4)	.967	1.020	1.000	1.033 (24)	.980 (23)	.990	.923
980	.973 (36)	.967	1.053	.970 (9)	.987 (8)	1.047	1.040	1.017 (3)	1.087	1.137 (25)	1.007	.990 (22)	.967	.933
27	.930	1.067	.893	1.070 (10)	1.103	1.113	1.097 (1)	1.017 (2)	1.023	.910	.970	.933 (21)	.950	.890
897	.953	.960	1.123	1.083 (11)	.993	1.127	1.077	1.053	1.057	1.103 (19)	1.023 (20)	.953	.960	.910
863	.930 (38)	.950 (39)	1.057	1.037	1.137 (12)	1.033	1.090	1.043	.993	1.037 (18)	1.040	.923 (50)	.950	.837
	.923	1.013 (40)	1.097	1.153	1.040	1.087 (13)	1.023	.970 (16)	1.057 (17)	.943	1.063	1.003	.920 (49)	
	.910	.963	1.010 (41)	1.073	1.090	1.037	.963 (14)	.990 (15)	1.043	.997	.993	.890	.863	
		.973	.937	.983 (42)	.927 (43)	1.033	1.083	1.023	.910 (47)	.970	.890 (48)	.930		
			.920	1.017	.960 (44)	.943	.960	.963	.927	.920	.897			
					.953	.980 (45)	.933 (46)	.930	.883					

A_2 Ave = .9962

A_2 Ave = 1.01

B_2 Ave = 1.006333

B_2 Ave = .97477

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

RC Press

Fig. 3

SPND STRING NUMBERS AND LOCATIONS – 177 FA CORE

[x] STRING NO.

Ave = 1.04098 (A2 quadrant) — Ave = .98[illegible] (A1 quadrant) — Ave = 1.00856 (B1 quadrant) — Ave = .965[illegible] (B2 quadrant)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					1.040	.977	1.000	1.077	1.063					
			1.023	1.140	1.050	[31] 1.017	[30] 1.047	.980	.930	.960	.967			
		1.023	1.103	1.060	[32] 1.020	1.040	1.000	[29] 1.057	[28] 1.043	1.003	.977	[52] .943		
	1.013	1.097	.980	[33] 1.163	1.033	1.000	1.080	1.010	[27] 1.000	.953	1.077	1.017	[51] .910	
	1.010	1.027	[34] 1.133	1.080	1.077	[7] 1.070	1.060	[5] 1.040	.960	[26] 1.033	.933	.960	.970	
[illegible]63	.990	[35] 1.033	1.057	1.103	1.130	[6] 1.010	[4] .950	.953	1.123	.953	[24] .957	[23] .967	.980	.89[illegible]
[illegible]000	[36] 1.007	1.030	1.047	[9] 1.000	[8] 1.003	1.053	.993	[3] .947	1.037	[25] 1.073	.960	[22] .913	.910	.89[illegible]
[37] [illegible]7	.947	1.097	.993	[10] 1.087	1.107	1.120	[1] 1.070	[2] .973	.960	.890	.940	[21] .913	.950	.8[illegible]
[illegible]10	.953	.977	1.143	[11] 1.120	.983	1.153	1.047	1.030	1.047	[19] 1.070	[20] 1.013	.937	.940	.93[illegible]
[illegible]43	[38] .930	[39] .950	1.093	1.060	[12] 1.153	1.003	1.080	.950	.983	[18] 1.033	1.013	[50] .920	.937	.82[illegible]
	.913	[40] .997	1.060	1.153	1.023	[13] 1.087	1.027	[16] .967	[17] 1.073	.943	1.043	.990	[49] .917	
	.897	.950	[41] .983	1.127	1.103	1.057	[14] .963	[15] 1.003	1.057	1.003	1.000	.883	.857	
		.927	.930	[42] .963	[43] .940	1.063	1.103	1.037	[47] .913	.977	[48] .887	.943		
			.910	1.017	[44] .953	.977	.983	.980	.930	.907	.907			
					.910	[45] .960	[45] .920	.923	[46] .850					

A2 — A1 — B1 — B2

549150

OWNER

PROJECT

JOB NO.

RC PRESS

Fig. 4

SPND STRING NUMBERS AND LOCATIONS — 177 FA CORE

K STRING NO

Ave = 1.0489

Ave = 1.0

A2

A1

				.950	.953	.963	1.010	1.020					
		.977	1.040	1.023	31 .963	30 1.020	.997	.993	1.007	1.027			
	1.010	1.053	1.040	32 1.013	1.050	1.020	29 1.050	28 1.040	1.030	1.050	52 1.033		
1.033	1.060	1.023	33 1.170	1.077	1.027	1.070	1.057	27 1.040	1.003	1.157	1.100	51 1.027	
1.010	1.063	34 1.090	1.100	1.097	7 1.090	1.063	5 1.063	1.030	26 1.123	1.017	1.040	1.030	
027 1.037	35 1.013	1.080	1.120	1.147	6 1.060	4 1.043	1.073	1.087	1.063	24 1.050	23 1.080	1.120	1.07
.167 36 1.090	1.077	1.093	9 1.030	0 1.053	1.077	1.037	3 1.003	1.043	25 1.093	1.017	22 1.047	1.047	1.04
37 3 1.013	1.040	.983	10 .997	1.040	1.027	1 1.060	2 1.013	.867	.877	.817	.910 21	.953	.95
790 1.053	1.000	1.140	11 1.027	1.030	1.070	1.033	1.033	1.040	19 1.100	20 1.037	1.050	1.033	1.07
.003 38 1.013	39 1.013	1.073	1.073	12 1.117	1.083	1.077	1.027	1.007	18 1.043	1.067	50 1.043	1.057	1.00
1.013	40 1.060	1.067	1.067	1.037	13 1.043	1.043	16 1.013	17 1.040	.977	1.010	1.013	49 .977	
.997	1.020	41 1.003	1.050	1.053	.950	14 .877	15 .863	.950	.853	.877	.833	.830	
	.813	.827	42 .817	43 .770	.840	.873	.857	47 .757	.683	40 .717	.787		
		.730	.793	44 .777	.770	.810	.863	.827	.953	.867			
				.853	45 .900	46 .837	.837	.797					

B2

B1

Ave = .97314

Ave = .938

549151

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

JOB NO.

RC PRESS ______

STRING NO.

Fig. 5

BEST ESTIMATE OF core inlet flow factors for 1 pump operation 177 FA plants

Ave = 1.[illegible]95 (A2) — Ave = 1.05[illegible] (A1)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					.936	.939	.963	1.025	1.035					
			.963	1.025	1.008	(31) .949	(30) 1.020	1.012	1.008	1.022	1.042			
		.[illegible]	1.038	1.025	(32) .998	1.035	1.020	(29) 1.065	(28) 1.055	1.045	1.065	(52) 1.043		
	1.018	1.[illegible]	1.008	(33) 1.153	1.061	1.012	1.070	1.073	(27) 1.055	1.018	1.174	1.116	(51) 1.042	
	.995	1.[illegible]	(34) 1.074	1.084	1.081	(7) 1.074	1.063	(5) 1.079	1.045	(26) 1.140	1.032	1.055	1.045	
.012	1.022	[illegible]	1.064	1.104	1.130	(6) 1.044	(4) 1.043	1.089	1.103	1.079	(24) 1.065	(23) 1.096	1.127	1.107
150	(36) 1.074	[illegible]	1.077	(9) 1.015	(8) 1.038	1.061	1.037	(3) 1.013	1.058	(25) 1.109	1.032	(22) 1.062	1.062	1.055
(37) .3	1.013	1.[illegible]	.983	(10) .997	1.040	1.027	(1) 1.060	(2) 1.013	.967	.877	.817	(21) .910	.953	.95[illegible]
990	1.053	1.[illegible]	1.140	(11) 1.057	1.030	1.070	1.033	1.033	1.040	(19) 1.100	(20) 1.037	1.050	1.033	1.077
.003	(38) 1.013	1.[illegible]	.073	1.073	(12) 1.117	1.083	1.077	1.027	1.007	(18) 1.043	1.087	(50) 1.043	1.057	1.007
	1.013	1.[illegible]	.067	1.067	1.037	(13) 1.043	1.043	(16) 1.013	(17) 1.040	.977	1.010	1.013	(49) .997	
	.997	[illegible]	(41) .003	1.050	1.053	.950	(14) .877	(15) .863	.950	.853	.877	.833	.830	
		.[illegible]	.827	(42) .817	(43) .770	.840	.873	.857	(47) .757	.683	(48) .717	.787		
			.730	.793	(44) .777	.770	.910	.863	.827	.853	.867			
					.853	(45) .900	(46) .837	.837	(46) .777					

B2 — B1

Ave = .97[illegible] — Ave = .9385

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POOR ORIGINAL

JOB NO.