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U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Gentlemen:

Subject: Oyster Creek Nuclear Generating Station (OCNGS)
Docket No. 50-219
Facility Operating License No. DPR-16
Oyster Creek Fuel Channel Bowing

Reference: GPU Nuclear Letter C321-91-2214, "Oyster Creek Fuel Channel Bowing," August 9, 1991.

In the referenced letter, GPU Nuclear committed to submit the results of the revised bow model being developed for the fuel channel reuse program at Oyster Creek. Attachment 1 to this letter provides a detailed description of the revised bow model, comparisons (based on the revised model) of measured versus predicted bows, revised model predictions of end-of-cycle (EOC) 13 bows, and resulting changes in Critical Power Ratio (CPR) penalty.

The revised model provides an improved method of predicting large channel bows resulting from fixed and variable gradient fluences of opposite channel faces. This model is now the basis for determining the channel average and core average channel bow which is used to determine the magnitude of the CPR channel bow penalty. The new R Factors calculated with the results from this model are somewhat larger than the original and will be used for the remainder of cycle 13. The increased R factors resulted from high bow channels residing in rodded control cells or other non-limiting core locations. The decrease in the calculated CPR results from the overall correction to the non-limiting core locations when applied to the limiting core locations. Continued operation with the higher bows is acceptable since the higher bows are located in control cells or non-limiting regions of the core. The R factors have been adjusted to correct CPR for the increased peaking. Thermal margin for axial power heat generation rate (APHGR) and local linear heat generation rate (LLHGR) in this region is sufficient to account for any additional

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uncertainty due to higher bows. In addition the bows are away from the control rod and will not interfere with control rod movements. Therefore, the new core average bow and larger reused channel bows will not affect the safe cycle 13 operation of Oyster Creek.

At this time, the impact of large bowed reused channels to the Oyster Creek channel reuse program has not been determined. A study to identify a channel management program which will minimize the development of large bows has been initiated. GPU Nuclear will inform the NRC of fuel channel reuse at Oyster Creek for cycle 14 and beyond prior to the next refueling.

If you have any questions or comments on this submittal please contact Mr. Michael Laggart, Manager, Corporate Nuclear Licensing at (201) 316-7968.

Very truly yours,

J. C. DeVine, Jr.
Vice President and Director
Technical Functions

JCD/RZ/plp
cc: Administrator, Region 1
Senior Resident Inspector
Oyster Creek NRC Project Manager

ATTACHMENT 1

TABLE OF CONTENTS

1.0 Background

The end-of cycle (EOC) 12 Oyster Creek fuel channel measurements, for the first time, measured channels having exposures of greater than 62 GWD/MTU. Some of these channels were found to have channel bows greater than 200 mils and as high as 400 mils. Bows of this magnitude were unexpected and appeared to originate from reused channel residence in the control cells. Reference 1 reported the results of the EOC 12 channel measurements and the comparison of the data to the calculated channel bow.

The original channel bow predictions were based on an empirical model. This model correlated Oyster Creek channel measurements and included only the initial cycle of control cell operation. It did not include any high exposure reused channels. This model did not predict the presence of large bows in the control cells. Since the original bow model could not be readily modified to account for this behavior, it was concluded that a new model divorced from the measurement data would be developed. The new model would be based on the individual channel history of Zircaloy growth resulting from calculated neutron fluence gradients.

2.0 Description of the NEWBOW Model

The revised Oyster Creek fuel channel bow model predictions, are based on the calculated differential growth of each face of the channel. The channel face growth is modeled from the Zircaloy growth curve published by ABB as part of the documentation of the Oskarshamn incident (Reference 2). The bow is calculated using the formula published in Reference 3, and uses the differential growth of opposing channel faces. It also accounts for the as-built channel bow.

The **NEWBOW** model calculates growth of each channel face based on: (1) local fixed flux gradients and (2) variable flux gradients. The growth due to these flux gradients results in channel bow about each axis. A negative bow indicates the bow is the direction of the control rod.

3.0 Fixed Gradient Bow Calculation

The fixed gradient bow is that portion of the total bow which results from the differential fluence originating from the design of the 'D' fuel cell lattice. The fixed gradient bow calculation is based on the calculated increased length of each channel face which results from the differential fluence at each face. The increased length is calculated using the growth to burnup relationship shown in Figure 1 (Reference 2). The exposure term used in the correlation is the product of the total channel exposure and fast fluence factor for the applicable face of the channel. The fast fluence factors were derived from PDQ neutronic calculations which modeled the explicit fuel cell geometry. The correlation for the length of each channel face is:

Increased Length of each Channel Face = f (E, FFF)

where: E is total channel exposure and FFF is the applicable fast fluence factor

The channel's bow about each axis is calculated using the equation found in Reference 3.

$$BOW = (L * \Delta L) / (8 * (W))$$

where: L is the channel length, ΔL is the difference in opposite channel face length, and W is the width of the channel

The delta lengths used in this equation are the differences between the growth of opposite channel faces lengths as calculated from the above correlation.

4.0 Variable Gradient Bow Calculation

The variable gradient bow is that portion of the total bow which results from the differential fluence of the channel faces due to the presence of control rods, locations at or near the core edge or due to radial power differences. The variable gradient bow correlation uses the same channel face length equation as the fixed gradient bow correlation, however, the channel face exposure term is the average of the fuel bundle containing the subject channel and the adjacent fuel bundles summed over the number of cycles the channel resided incore. The increase length of the channel face correlation is:

Increased Length of Each Channel Face = f (E')

where: E' is total average channel face exposure

The variable gradient channel bow about each axis is calculated as above using the same equation from Reference 3.

5.0 Total Bow

The total bow about each axis (i.e. X and Y bows) for the required cycle is the sum of the fixed gradient, variable gradient bows and the addition of the average as-built bow of 15 mils.

X or Y Total Bow = Fixed Gradient + Variable Gradient Bows + As-Built Bow

6.0 Average Bow

The average bow is the average of the total X and Y bows. This value is used to determine the fuel channel bow penalty.

Average Bow = (Total X Bow + Total Y Bow)/ 2

7.0 Results of the NEWBOW Model

The goal of the **NEWBOW** model is to provide a better agreement between prediction and measurements for both the magnitude and direction of channel bow. The predictions of **NEWBOW** were compared to the Oyster Creek channel measurements. Bows at higher exposures were of particular interest because they had previously been under predicted.

The measured versus predicted bows are shown in Figure 2. The data includes channels with varied core location histories including edge core and control cell (rodded) operation. This figure also shows the one sigma error band of 53.7 mils associated with the 107 data points. This data includes all the Oyster Creek channels which were measured more than once.

Figures 3 and 4 are examples how the **NEWBOW** correlation can predict the change in direction of the channel bow as compared to the measured bow. Keep in mind that this data was not used to correlate the model.

The projected EOC 13 core average channel bow as calculated by **NEWBOW** is 58 mils. The error associated with this prediction is, as stated above, 53.7 mils. The error associated with the previous model which includes the EOC 12 measurements is 68.9 mils. The new model is an improvement over the previous model due to the use of the differential fluence to calculate edge core and control cell operating history

bows.

Figure 5 is a core map which shows the predicted average channel bow at the EOC 13. The high bow channels resulted from channel histories which resided in low power and high differential flux core location such as control cell and edge core locations.

8.0 The Effect of Large Predicted Channel Bow on Cycle 13 Operation

The EOC 13 average channel bows were evaluated to determine the effect on the channel bow CPR penalty. Average channel bows of greater than 200 mils were analyzed. It was determined that the fuel in the cells containing the large average bows did not become limiting following the additional CPR penalty. The fuel bundles with the largest channel bows were located in rodded control cells or in other non-limiting core locations. The new R-factors resulting from the newly calculated bows will be used in cycle 13 operation. The new CPR penalty will add another 2%, for a total of 6% additional CPR in the limiting core locations resulting from channel bow. The CPR penalty for non-limiting core locations is higher.

9.0 Conclusions

The **NEWBOW** model provides an improved method of predicting large channel bows resulting from fixed and variable gradient fluences of opposite channel faces. This model is now the basis for determining the channel average and core average channel bow which is used to determine the magnitude of the CPR channel bow penalty. The new R Factors calculated with the results from this model are somewhat larger than the original and will be used for the remainder of cycle 13. The increased R factors resulted from high bow channels residing in rodded control cells or other non-limiting core locations. The decrease in the calculated CPR results from the overall correction to the non-limiting core locations when applied to the limiting core locations. Continued operation with the higher bows is acceptable since the higher bows are located in control cells or non-limiting regions of the core. The R factors have been adjusted to correct CPR for the increased peaking. Thermal margin for APHGR and LLHGR in this region is sufficient to account for any additional uncertainty due to higher bows. In addition the bows are away from the control rod and will not interfere with control rod movements. In conclusion, the new core average bow and larger reused channel bows will not affect the safe cycle 13 operation of Oyster Creek.

10.0 References

1. GPU Nuclear Letter C321-91-2214 (to NRC), "Oyster Creek Fuel Channel Bowing", August 2, 1991.

2. OKG AB and ABB ATOM AB Poster Presentation, Subject "In-Reactor Mechanical Behavior of BWR Fuel Channels", Ake Johnson, Lars Hallstadius, Ulf Sundstrom, 1990.

3. EPRI Report NP-2483, Title "An Assessment of BWR Channel Lifetimes", July 1982.

11.0 Figures

ZIRCALOY GROWTH CURVE
(Reference 2)

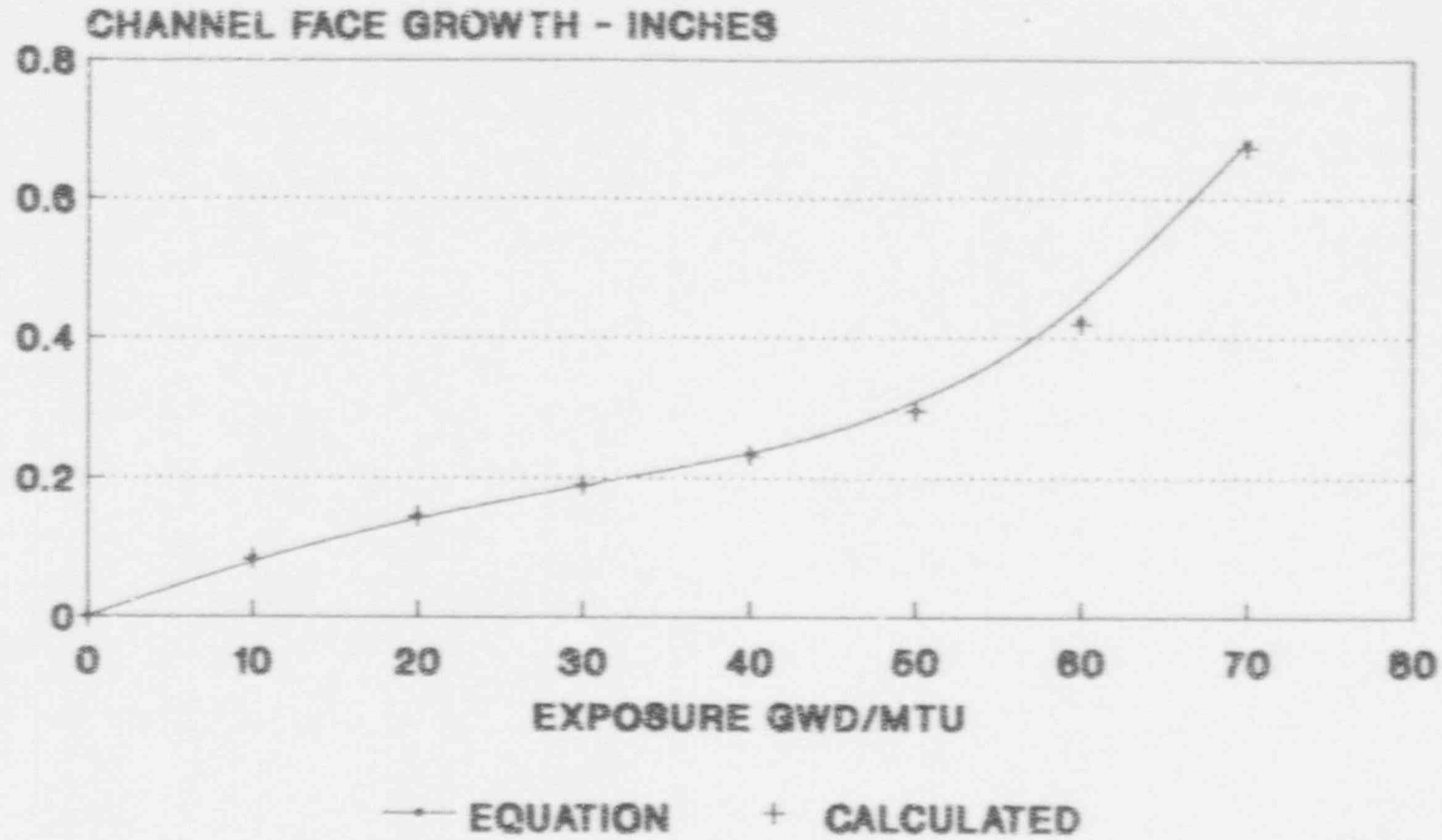

Figure 1

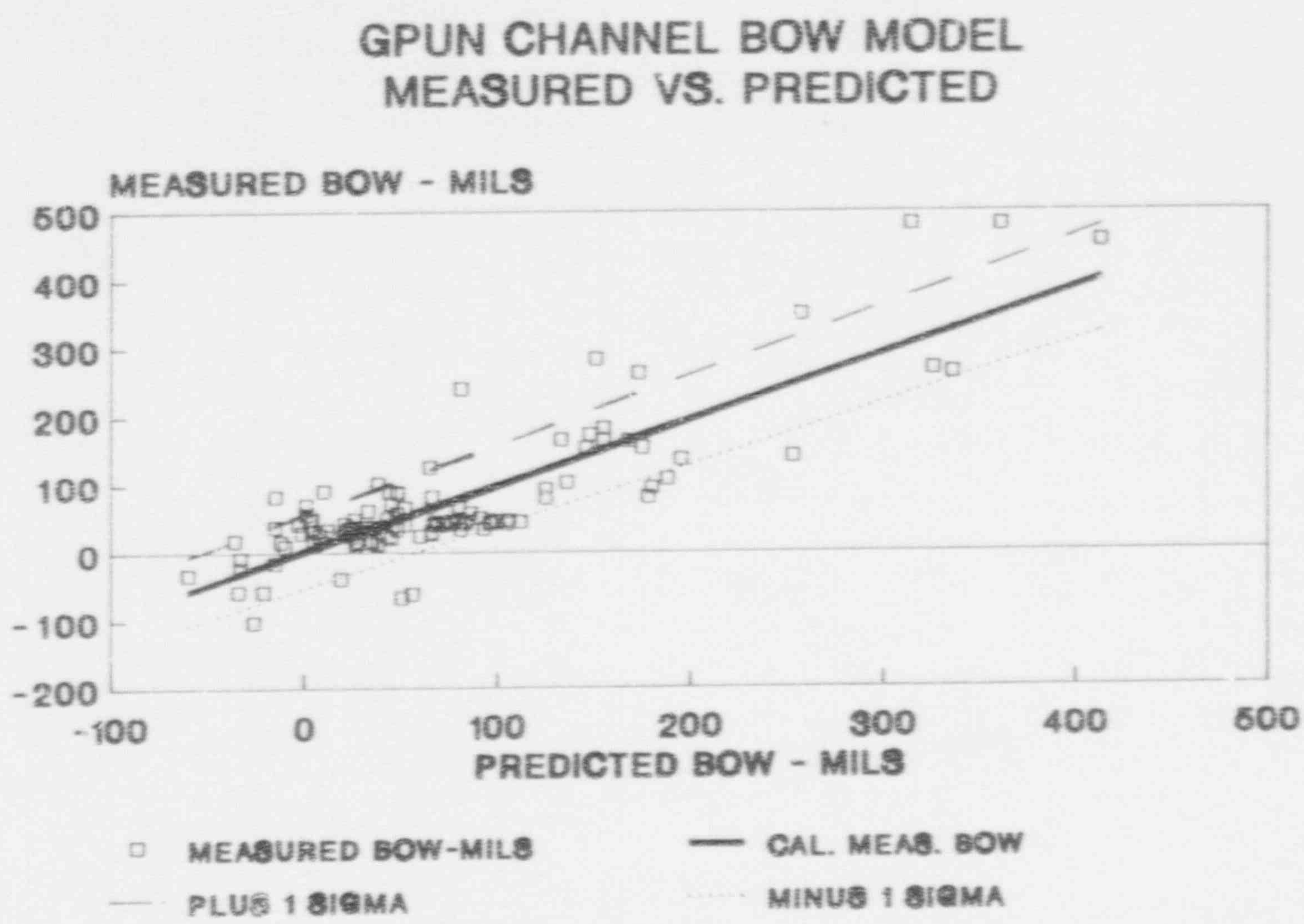
GPUN CHANNEL BOW MODEL
MEASURED VS. PREDICTED
MEASURED BOW - MILS
500
400
300
200
100
0
-100
-200
-100
0
100
200
300
400
500
PREDICTED BOW - MILS
MEASURED BOW-MILS
CAL. MEAS. BOW
PLUS 1 SIGMA
MINUS 1 SIGMA

Figure 2

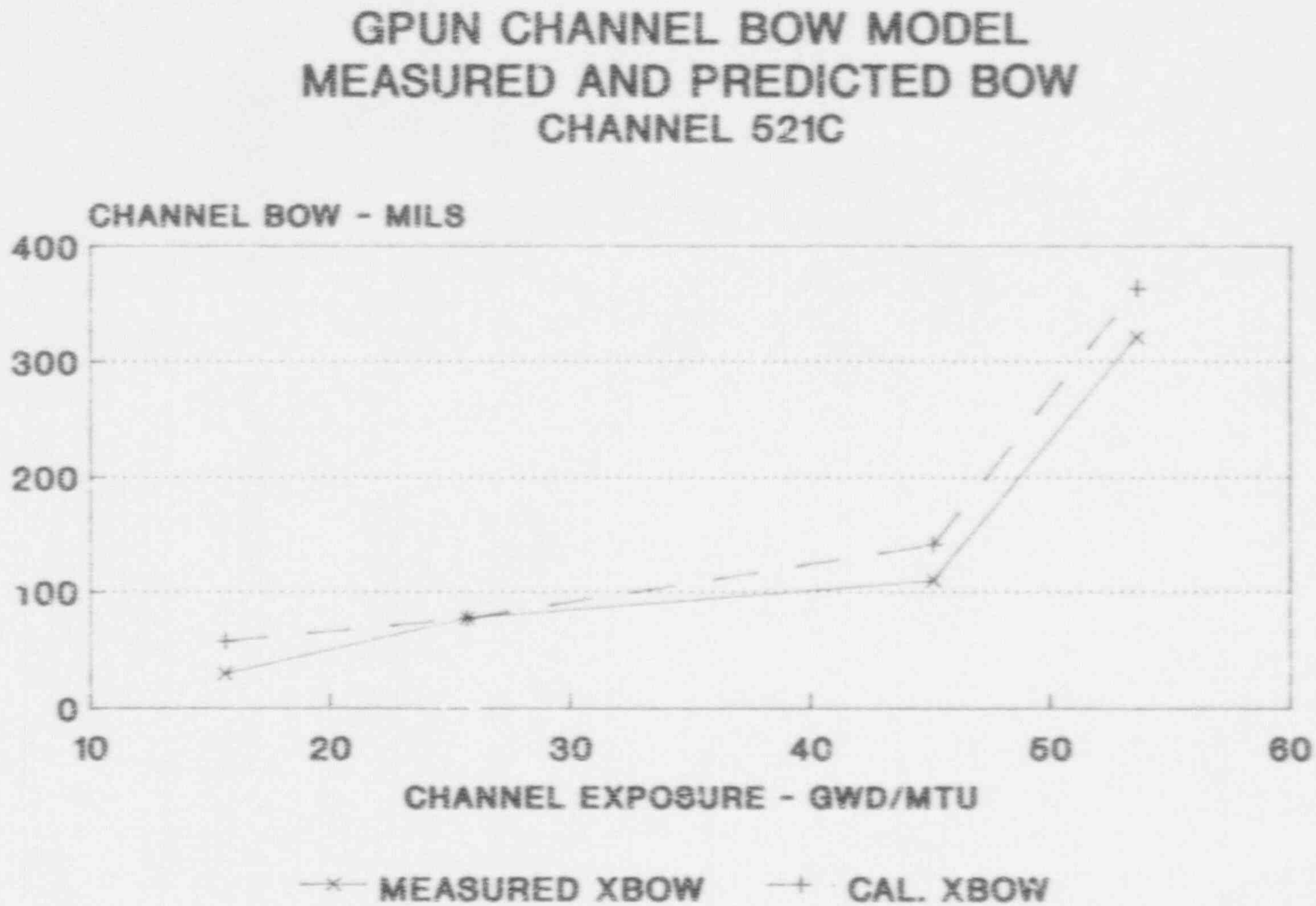
GPUN CHANNEL BOW MODEL
MEASURED AND PREDICTED BOW
CHANNEL 521C
CHANNEL BOW - MILS
400
300
200
100
0
10
20
30
40
50
60
CHANNEL EXPOSURE - GWD/MTU
MEASURED XBOW
CAL. XBOW

Figure 3

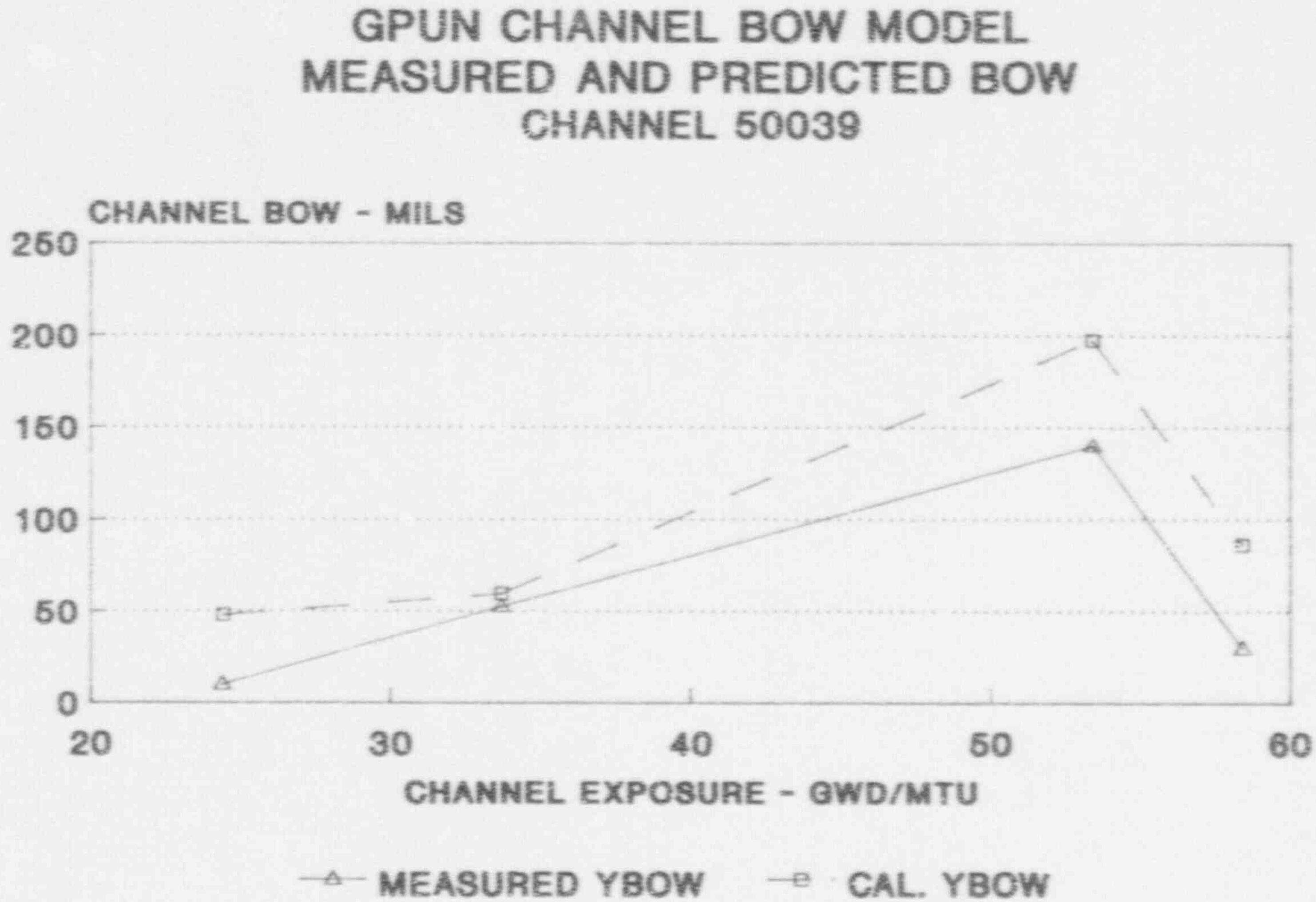
GPUN CHANNEL BOW MODEL
MEASURED AND PREDICTED BOW
CHANNEL 50039
CHANNEL BOW - MILS
250
200
150
100
50
0
20
30
40
50
60
CHANNEL EXPOSURE - GWD/MTU
MEASURED YBOW
CAL. YBOW

Figure 4

PREDICTED EOC 13 AVERAGE CHANNEL BOWS (MILS)

1	—	—	—	—	—	—	—	—	-38	16	-38	13	31	31	13	-40	16	-19	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	107	44	100	156	97	68	68	68	100	100	44	86	—	—	—	—	—	—	—
3	—	—	—	—	32	57	40	25	0	25	26	24	25	25	24	26	27	0	25	-4	57	31	—	—	—	—
4	—	—	—	186	21	59	82	68	17	21	143	50	17	18	45	153	21	17	68	69	57	21	188	—	—	—
5	—	—	-11	29	172	56	-2	35	47	72	12	17	75	75	18	29	72	47	35	-2	56	115	26	-12	—	—
6	—	—	161	57	59	66	20	62	65	53	27	5	61	61	5	28	53	65	62	56	66	59	57	166	—	—
7	—	—	-5	77	-3	19	48	77	24	131	56	35	17	17	35	56	36	24	77	48	19	-3	69	-5	—	—
8	—	98	27	68	36	83	77	40	163	23	94	55	95	156	55	94	23	-6	40	77	73	36	68	27	98	—
9	-16	43	0	18	47	60	25	32	48	287	20	85	95	96	56	20	67	48	32	25	60	47	18	0	43	-16
10	37	100	21	20	100	54	35	24	64	-1	155	29	197	112	28	80	-1	64	24	36	54	100	20	68	100	37
11	-42	107	26	149	12	27	56	187	20	43	17	46	26	26	46	17	32	20	171	56	28	12	144	27	107	-44
12	6	63	25	50	17	5	32	179	45	29	63	112	162	157	56	45	28	45	64	32	5	18	50	24	92	44
13	-14	71	24	18	353	237	17	181	96	348	27	324	53	53	291	26	358	96	48	17	242	205	18	24	71	-14
14	-14	71	24	18	179	248	17	48	96	356	26	267	53	53	324	27	82	96	48	17	221	322	18	24	71	-14
15	44	63	25	50	17	5	32	54	124	28	45	68	164	163	51	45	28	65	100	32	5	18	60	24	63	94
15	-44	106	27	181	12	28	56	245	20	32	17	46	26	26	115	17	32	20	53	56	28	12	188	27	107	-39
17	37	100	21	20	100	54	35	24	64	-1	174	28	333	359	29	161	-1	64	24	36	54	100	20	21	100	38
18	-16	43	0	18	47	60	25	32	48	67	20	63	95	95	63	20	67	48	32	25	60	47	18	0	76	-16
19	—	98	27	68	36	68	77	40	188	23	195	55	101	86	133	34	23	175	40	77	50	36	68	27	98	—
20	—	—	-5	72	-3	19	48	76	24	36	56	35	15	18	36	56	36	24	77	48	15	-3	85	-5	—	—
21	—	—	77	83	59	66	21	56	65	53	28	5	61	52	5	27	53	65	83	20	66	59	57	77	—	—
22	—	—	-12	26	172	56	-2	35	47	72	12	18	75	75	67	51	72	47	82	-2	56	138	26	-12	—	—
23	—	—	—	187	21	56	72	68	17	21	196	40	17	17	50	34	21	17	68	71	57	22	187	—	—	—
24	—	—	—	—	31	58	-4	25	0	25	26	24	25	25	89	26	25	0	52	-4	57	2	—	—	—	—
25	—	—	—	—	—	—	—	86	44	101	126	68	208	105	99	126	101	44	86	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	-56	16	-40	12	31	31	13	-19	16	-55	—	—	—	—	—	—	—	—
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

FIGURE 5