TENNESSEE VALLEY AUTHORITY
ENGINEERING LABORATORY

EFFECTS OF BLOCKED RHR SUMP SCREENS ON TRASHRACK HEADLOSS, NET POSITIVE SUCTION HEAD, AND VORTEXING PROPENSITY AT WATTS BAR NUCLEAR PLANT

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INTRODUCTION

The final design for the RHR sump at Watts Bar Nuclear Plant (WBN) was developed with the aid of a physical model study performed by TVA at the Engineering Laboratory, Norris (Fain, 1979). At the request of the Project Engineer, Watts Bar Engineering Project (Mandava, 1989), the notebooks, final report, and other documents associated with the model study were reviewed in order to determine the effects of blocked screens on trashrack headloss, net positive suction head, and vortexing propensity. This report presents results and conclusions from the review.

The final design recommended in the model study report is shown in Figure 1 for reference. The sump is located in the 8-foot high passageway under the refueling canal. Both entrances to the passageway are provided with steel trashracks and 1/4-inch mesh screens (trashrack screens). A second 1/4-inch mesh screen is located inside the sump (internal screen). The "as constructed" configuration of the screens and trashracks can be found on TVA Drawing 85-S-48N919-R15 (FSAR Fig No. Q22.12-10). A photograph of a trashrack screen is shown in Figure 2 for visualization. As the drawing and photograph indicate, the trashrack screens were inadvertently placed on the upstream side of the trashracks, rather than on the downstream side.

HEADLOSS

Headloss (differential pressure) across the respective screens was computed as a function of percent screen blockage using the methods referenced in the model study report (Fain, 1979) and completely described in a previous TVA report (TVA, 1976). A constant sump discharge of 19,000 gallons per minute (gal/min) at 190°F was assumed,

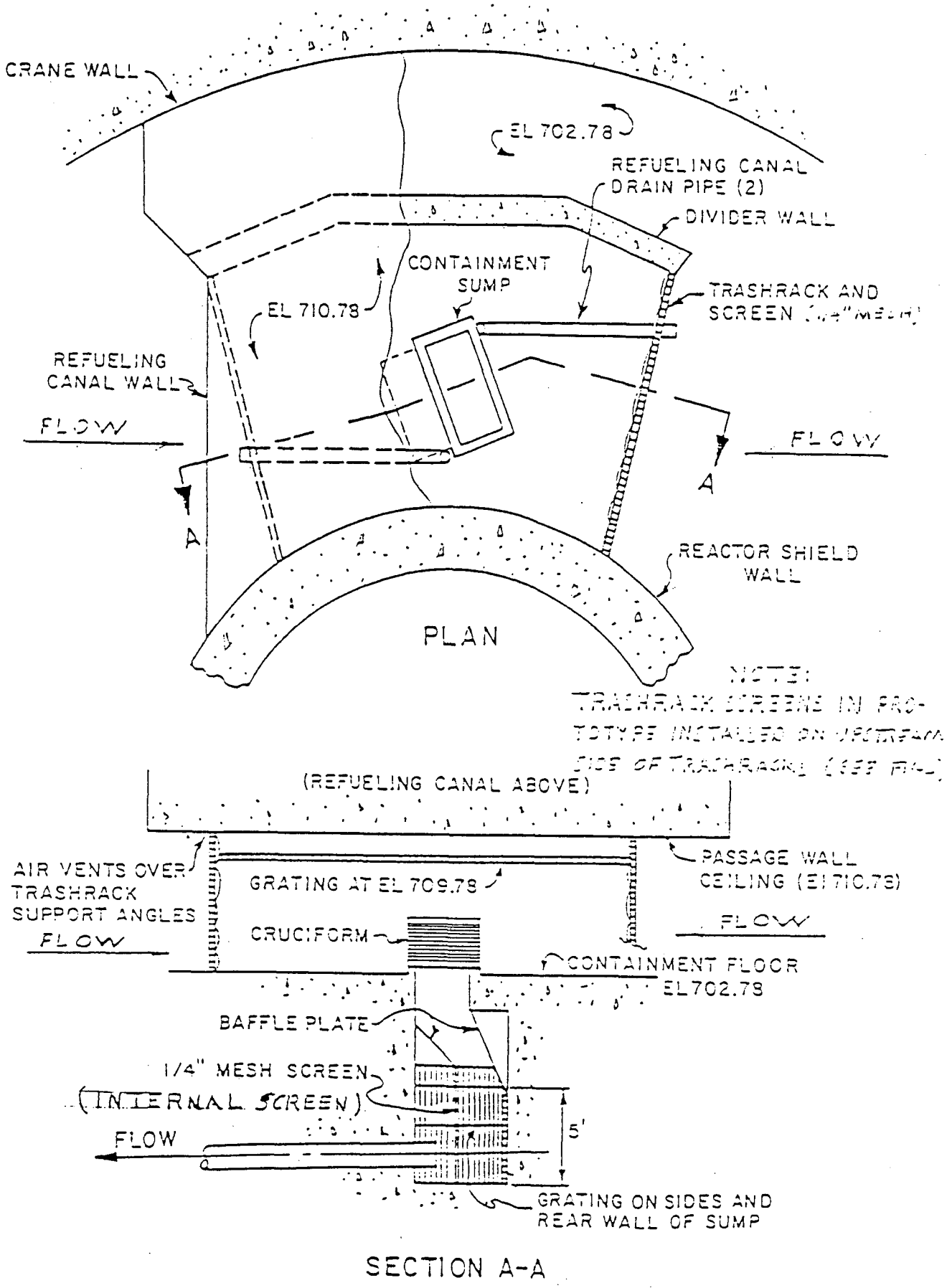

Figure 1: Final Recommended Sump Design

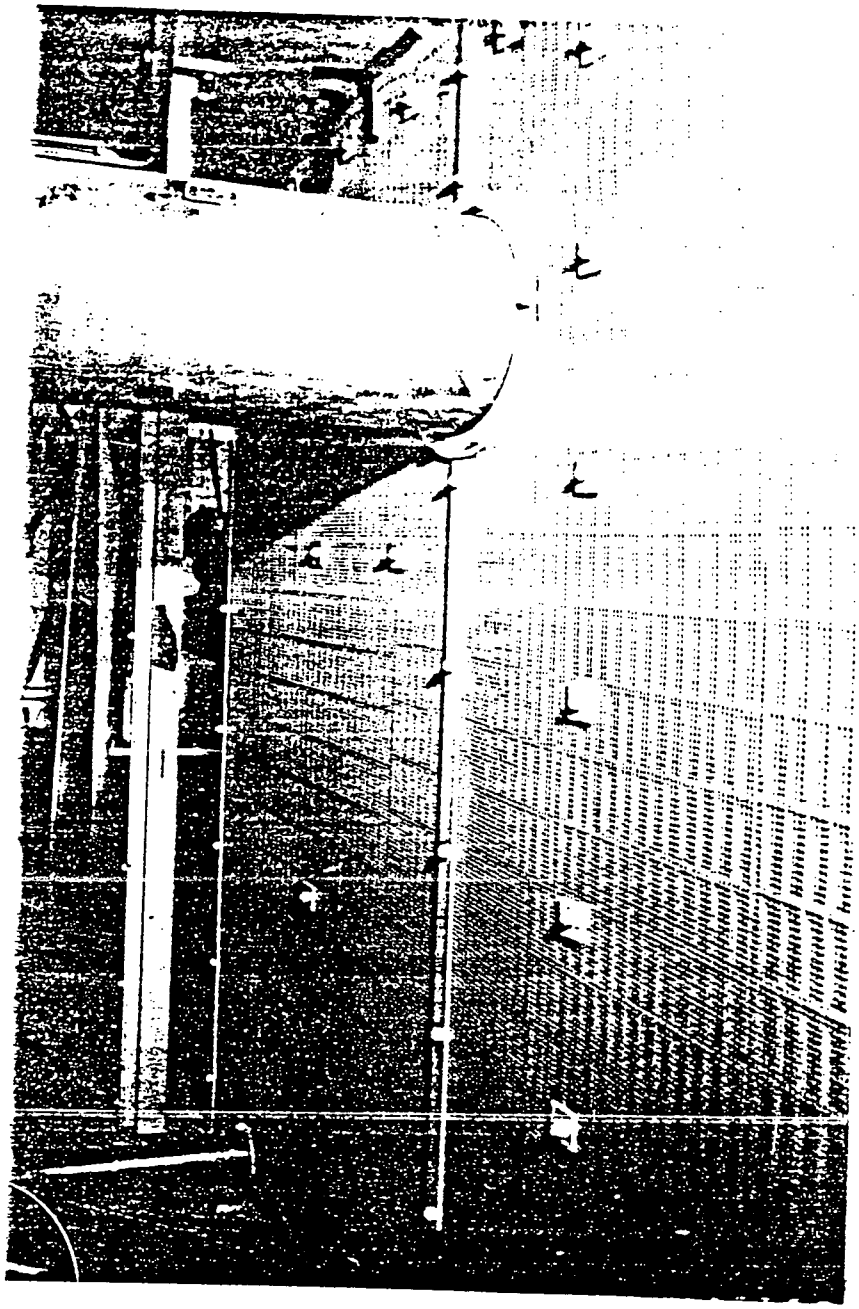

Figure 2: Photograph of Trashrack Screen
(Looking Downstream)

and "as built" dimensions of the screened areas, wire diameter, wire mesh, and trashrack bars were used. Results of the computations are presented numerically in Tables 1 and 2, and graphically in Figures 3 and 4.

With 50 percent of each screen blocked, calculated headloss values for the trashrack and internal screens were 0.01 and 0.8 inches of water, respectively. Together, the two blocked screens contribute about seven percent to the total sump headloss.

NET POSITIVE SUCTION HEAD

The excess net positive suction head (NPSHE), which is the positive suction head in excess of the net positive suction head requirement (NPSHR), had been previously computed using the headloss for unblocked screens (Mills, 1982). NPSHE as a function of percent screen blockage was computed by adding the total screen headloss for unblocked screens to the published NPSHE value, and then subtracting the total screen headloss for blocked screens. A constant discharge of 19,000 gal/min at 190°F was assumed.

The results, presented in Table 3, indicate that simultaneous 50 percent blockage of both screens would reduce NPSHE from 14.4 feet to 14.3 feet (0.4 percent).

EFFECT OF SCREENS ON VORTEXING PROPENSITY

The propensity for vortex formation at the sump depends on the velocity field in the vicinity of the sump. Screens affect that velocity field by providing resistance to flow, thereby changing the directions of streamlines approaching the sump. Vortexing tendencies are exacerbated when sections of the screens are solidly blocked, especially in axisymmetric patterns which allow couples of jets to approach the sump. Accordingly, tests with various patterns of trashrack screen blockage were included in the referenced model study. The worst case, as observed in the model study, was with 50 percent of each trashrack screen blocked

TABLE 1

Trashrack Screen Headloss

Percent Blocked	Reynolds Number	Headloss Coefficient	Headloss (Inches of Water)
0*	204	0.568	0.004
5	215	0.565	0.004
10	227	0.562	0.005
15	241	0.559	0.005
20	256	0.556	0.006
25	273	0.554	0.007
30	292	0.551	0.007
35	315	0.548	0.009
40	341	0.545	0.010
45	372	0.542	0.012
50**	409	0.540	0.014
55	454	0.537	0.018
60	511	0.534	0.022
65	584	0.531	0.029
70	682	0.528	0.039
75	817	0.526	0.056
80	1022	0.523	0.087
85	1363	0.520	0.154
90	2045	0.517	0.344

*Unobstructed upstream velocity = 0.19 foot per second.
**Computation was extended to 90 percent blockage to illustrate the headloss trend. Maximum design blockage was 50 percent.

TABLE 2

Internal Screen Headloss

Percent Blocked	Reynolds Number	Headloss Coefficient	Headloss (Inches of Water)
0*	1560	0.519	0.201
5	1642	0.519	0.223
10	1733	0.518	0.248
15	1835	0.518	0.278
20	1950	0.518	0.313
25	2080	0.517	0.356
30	2229	0.517	0.409
35	2400	0.516	0.474
40	2600	0.516	0.555
45	2836	0.516	0.660
50**	3120	0.515	0.799
55	3467	0.515	0.985
60	3900	0.515	1.246
65	4457	0.514	1.626
70	5200	0.514	2.212
75	6240	0.514	3.183
80	7800	0.513	4.970
85	10400	0.513	8.829
90	15600	0.513	19.852

*Unobstructed upstream velocity = 1.44 feet per second.
**Computation was extended to 90 percent blockage to illustrate the headloss trend. Maximum design blockage was 50 percent.

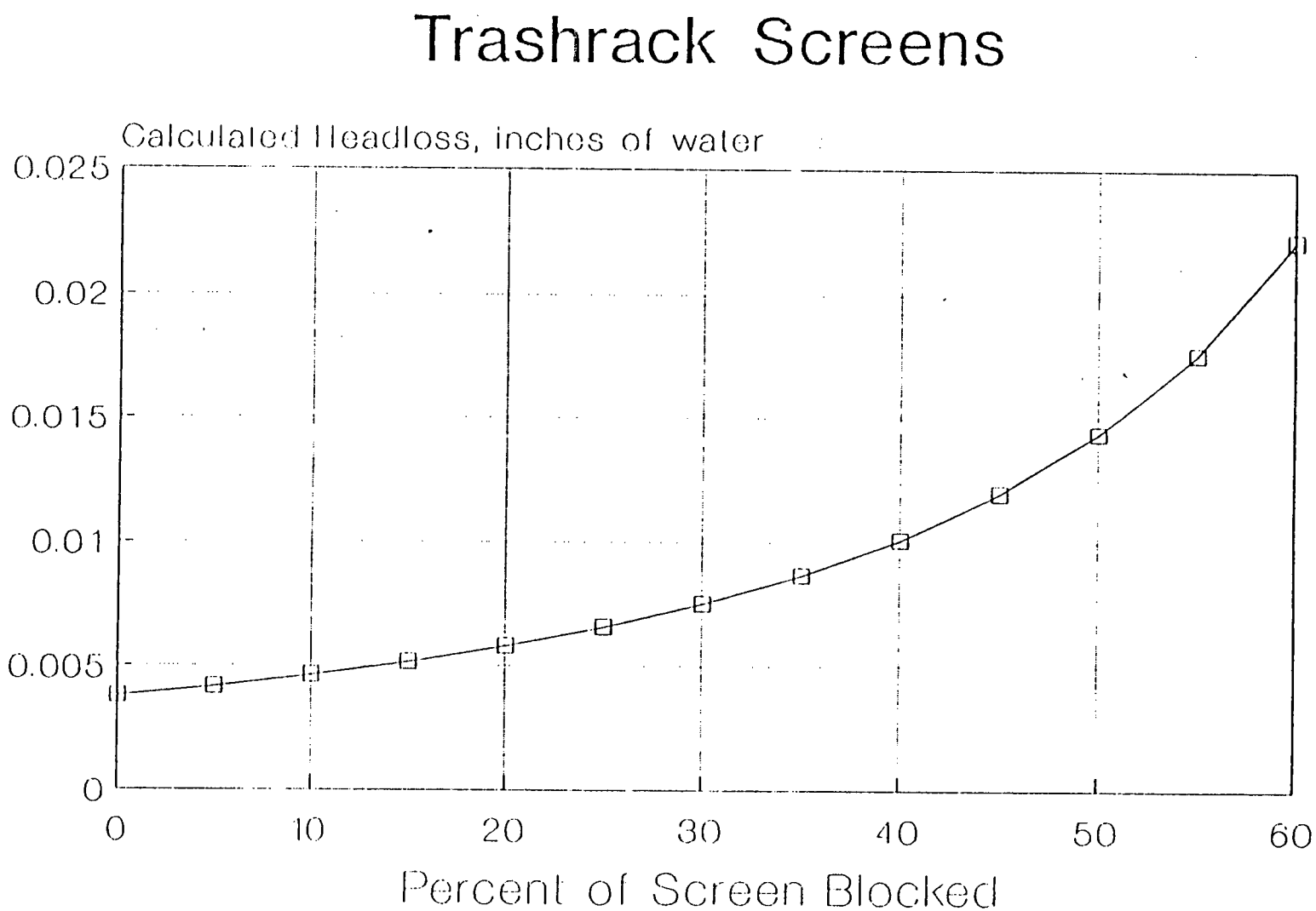

Figure 3: Trashrack Screen Headloss

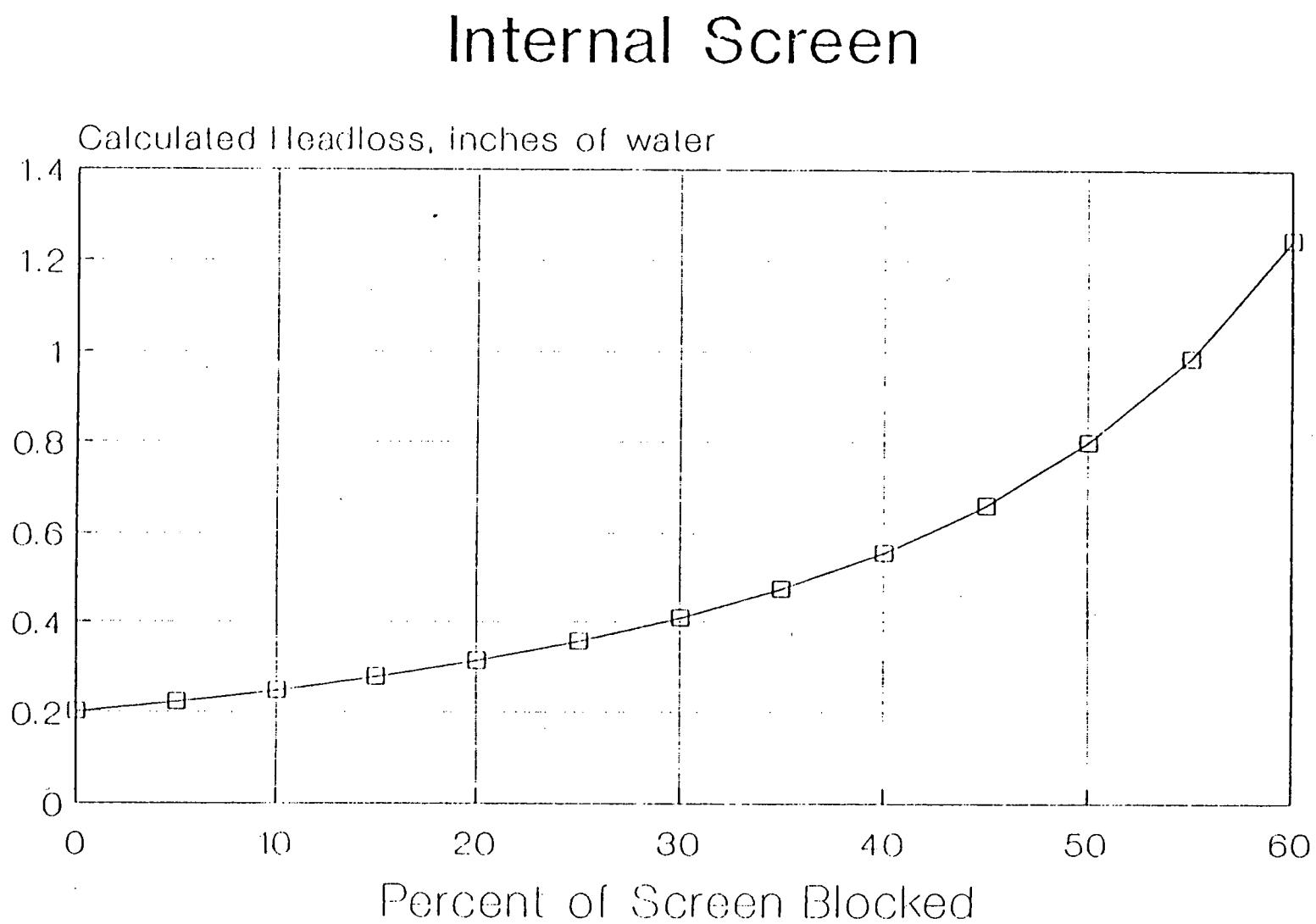

Figure 4: Internal Screen Headloss

TABLE 3

Excess Net Positive Suction Head

Percent Blocked (Both Screens)	Total Screen Headloss (Inches of Water)	NPSHE (Feet of Water)
0	0.205	14.365
5	0.227	14.363
10	0.253	14.361
15	0.283	14.359
20	0.319	14.355
25	0.363	14.352
30	0.416	14.347
35	0.483	14.342
40	0.565	14.335
45	0.672	14.326
50*	0.813	14.314
55	1.003	14.299
60	1.268	14.276
65	1.655	14.244
70	2.251	14.195
75	3.239	14.112
80	5.057	13,961
85	8.983	13.633
90	20.196	12.699

* Computation was extended to 90 percent blockage to illustrate the NPSHE trend. Maximum design blockage was 50 percent.

so that a strong couplet of jets formed around the sump approach. As noted in the final report (Fain, 1979), no vortices were observed even with this worst case pattern.

Model testing with internal screen blockage was not performed because observations during tests with only one sump discharge pipe operating indicated that strongly rotating flow inside the sump would not cause free surface vortexing. The tendency of vortices to form on the inside walls of the sump was eliminated by installing grating on the inside walls as shown in Figure 1.

Flow resistance provided by the trashrack screens is relatively small, indicating that screen influence on flow patterns near the sump would be negligible. Consequently, loss of one or both of the trashrack screens during operation of the sump would have no noticeable effect on vortexing propensity.

CONCLUSIONS

The computed value of the trashrack screen headloss with 50 percent screen blockage and 19,000 gal/min sump discharge at 190°F is 0.01 inch of water. The integrity of the trashrack can be verified by comparing the trashrack screen headloss with the maximum permissible load on the screen. Computation of the maximum permissible load was beyond the scope of this report.

Simultaneous 50 percent blockage of internal and trashrack screens would cause an insignificant (0.4 percent) reduction in NPSHE.

Vortexing tendencies at the sump due to blocked screens were eliminated in the final sump design developed by the model studies.

Loss of the trashrack screens would not increase the vortexing propensity of the sump.

The probable effect of an air-drawing vortex (if, contrary to expectation, one should occur) may also be considered. Measured levels of air ingestion with freestanding air-core vortices are generally less than one percent of the water volume (Padmanabhan and Hecker, 1982). On the other hand, performances of both axial-flow and radial-flow pumps are

not noticeably reduced by quantities of ingested air less than three percent (Murakami and Minemura, 1978). These conclusions were also included in a subsequent NRC report (Kamath, et al., 1982). No correlation was found between surface vortices and sump loss coefficients, which affect discharge capacity and net positive suction head (Weigand, et al., 1982). Therefore, the presence of an air-drawing vortex at Watts Bar should not significantly reduce the sump performance.

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