TEXAS UTILITIES GENERATING CO.
COMANCHE PEAK S.E.S.

ANALYSIS OF THE CLOGGING OF ECCS SUMP TRASH RACKS BY DEBRIS AND PAINT PEELS FOLLOWING AN ACCIDENT

FOR
TEXAS UTILITIES GENERATING CO.

BY

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ERRATA

FOR EBASCO REPORTS

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ρ_p = density of the peel

A = area of the peel

t = thickness of the peel

C_{Du} = drag coefficient for paint peel motion in vertical direction

C_{Dv} = drag coefficient for paint peel motion in horizontal direction

C_{Lu} = coefficient to account for the lift forces on paint peel motion

ρ_w = density of water

v_o = pool water velocity

u = paint peel vertical velocity

v = paint peel horizontal velocity

These equations (1) and(2) are numerically solved for paint peel horizontal and vertical terminal velocities. The results have been plotted on Figure 7.

An angle of zero would result in the longest vertical travel time. The furthest horizontal travel occurs at the angle for which the value of the multiplication of the horizontal velocity and the vertical travel time is the largest . As seen from Figure 7, the longest travel time occurs at a small angle. However, the equations used to model the paint peel fall are inappropriate at angles near zero and ninety degrees since boundary layer effects on drag have been ignored in the equations. Consequently, results at angles greater than 85° and less than 5° are not considered to be representative of actual conditions. Despite these assumption problems, the average horizontal travel distance for any paint peel can be calculated to fall between 22 and 24 feet using the information presented in Figure 7.

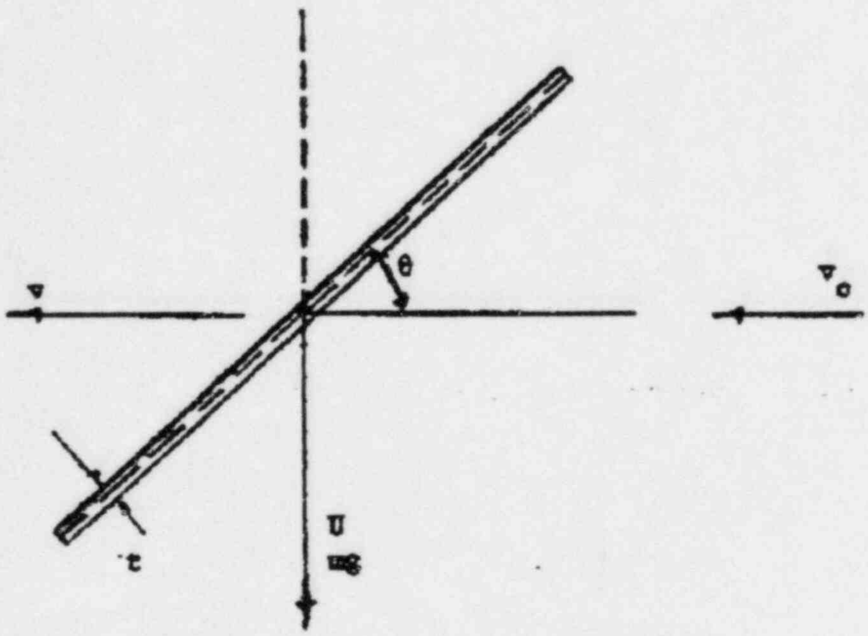

Figure 6

Paint Peel Force Model

The reaction at the metal surface equals 1051.3x0.3, or 315.4 lbf. Assuming a coefficient of friction of 0.1, the frictional force equals 31.54 lbf. The peel of area 1 ft^2 and thickness 0.03" weighs 0.2 lbf. Hence, the peel would indeed cling to the surface of the screen vertically.

Using Fig. 4, Consideration will be given to a vertical peel striking the water surface at a horizontal distance of x ft. from the trash rack. It will be conservatively assumed that the incident velocity equals zero. Since the drag on a vertically descending paint peel is small and negligible, the time t taken by the peel to fall through a distance of 16.875' is given by $\frac{1}{2} gt^2 = 16.875$ and is found to be 1.02 secs. While the peel descends verticaly, it would be transported to the screen by the velocity of the water. The water velocity is 0.161 ft/sec at the screen and it reduces with distance. It is conservatively assumed that the water velocity is a constant equal to 0.161 ft/sec and that the peel is transported without slip. The distance x is then equal to 0.161 t which is about 2" with t equal to 1.02 secs. Thus, the paint peels incident within 2 inches of the trash rack could be expected to clog the screen vertically.

Estimation of the Average Horizontal distance traveled by the Paint peels incident on the surface of the water at different angles:

Figure 6 illustrates a paint peel at an angle θ to the horizontal moving under water. The weight mg acts vertically downwards. The peel would fall down under the influence of mg opposed by drag and aerofoil type of lift forces. The equations of motion in the vertical and horizontal directions respectively are:

$$m \frac{du}{dt} = mg - \frac{C_{Du}}{2} \rho_w A \cos\theta \, U^2 \qquad (1)$$

$$m \frac{dv}{dt} = \frac{C_{Lu}}{2} A \cos\theta \, U^2 - \frac{C_{Dv}}{2} \rho_w A \sin\theta (v-v_o) |v-v_o| \qquad (2)$$

Where, m = mass of the peel = $At\rho_p$, and

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March, 1984

Executive Summary

Clogging of the trash racks covering the ECCS sumps, by paint peels and debris following an accident has been investigated, in order to assess the resultant effect on the performance of the ECCS pumps. Debris other than paint was assumed to fill half the depth around the trash racks as per the requirements in Regulatory Guide 1.82, Revision 0, even though application of R.G. 1.82 Rev. 1 shows that the plant possesses little or no possibility for debris transport. Factors like clogging of trash racks by paint peels sticking vertically to it, transport of paint peels to the vicinity of trash racks and the packing ratio of paint peels were investigated under accident conditions.

The ECCS pump performance was adjudged not affected, if the pressure drop across the trash racks were much less than the suction head of the pump. It is concluded that the performance of the ECCS pumps would not be adversely affected, if the trash racks were blocked 83% or less. Such a blocking limit could be reached if (1) debris exceeding about 4000 ft^3 fill the space around the trash racks, in addition to the total quantity of paint filling the same space with a packing ratio of 0.75 or, (2) if the entire quantity of paint fills the space around one trash rack with some of the paint peels clogging the screen by vertically sticking to it in addition to debris covering half its depth. Since the accumulation of all the paint inside the containment over and above the debris blocking half the depth of the trash rack is insufficient to exceed the 83% blockage, ECCS performance is adjudged not capable of being affected by trash rack clogging.

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1. Introduction

The main purpose of the ECCS pumps is to supply the containment sprays and reactor cooling system with water from the sumps located in the containment following a LOCA. These containment sumps are covered by trash racks 6'3" in height located at an elevation of 808.0 (Figure 1). Following a LOCA, debris and paint peels could accumulate around the trash racks causing an impediment to the flow of water to the ECCS pumps. This condition has been analyzed in order to determine the amount of blockage of the trash rack by paint peels and the effect on the performance of the pumps.

2. ECCS Suction System Description and Inputs

There are two trash racks, one covering each sump at 808.0' elevation (Ref. 1,2). Each trash rack is in the form of a partial sector in plan, subtending an angle of about 30° at the center of the containment, 8' in width and 6'3" in height. The perimeter of each trash rack is found to be about 80' and the area in plan is about 235.0 ft^2. The trash racks possess a free flow area of 70% (Ref. 3 and Appendix A). The nondimensional irreversible pressure loss coefficient for the trash rack calculated from experimental maximum pressure drop data with 95% confidence (Ref. 3 and Appendix A) was found equal to 28.0 with reference to the flow through a half clogged trash rack with 12500 gpm. As indicated in Table 1 (Ref.4), the volume of paint on concrete equals 831.25 ft^3. (285000 ft^2 with an average thickness of 0.035"). The volume of paint on steel equals 204.14 ft^3 with an average thickness of 0.01'. Further, there are about 17000 ft^2 of unqualified paint (Ref. 5) with an assumed thickness of 0.01"; the volume of this paint equals 14.2 ft^3. The total volume of all paints equals 1049.6 ft^3. The following information were not available from TUGC and were assumed: (1) The dry density of paint equals 80 lbm/$ft.^3$; this is the lower limit paint density from EBASCO constructed plants (2). The height of flood water above 808.0' equals 20.0'.

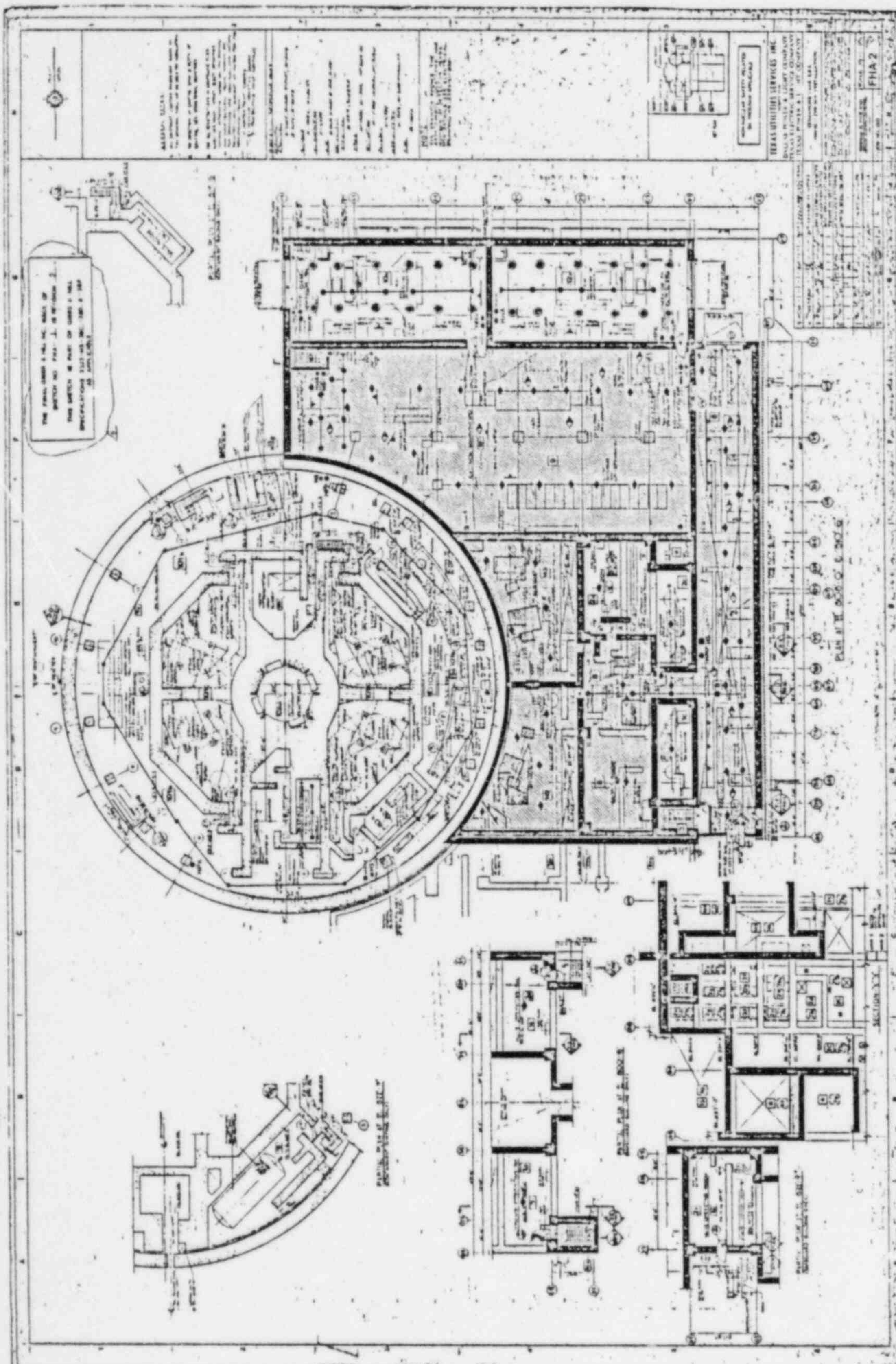


FIGURE I

TABLE I

PAINT DETAILS

DESCRIPTION	Painted Area ft^2	Average Thickness, inches	Paint Volume, ft^3
1. Concrete	285,000	0.035	831.25
2. Steel Liner	145000	0.01	120.83
Pipe Supports	4520 x 11 = 49720	0.01	41.43
Cable Tray Supports	755 X 11 = 8305	0.01	6.92
Conduit Supports	4812 X 8 = 38496	0.01	32.08
Miscellaneous	2500	0.01	2.08
Miscellaneous	87 X 11 = 957	0.01	0.80
3. Unqualified paint	17000	0.01	14.20
		Total	1049.59

3.1 Initial Blocking Analysis

As shown on Figure 2, and based on geometry considerations it was estimated (Ref. (4)) that an area of about 500 ft^2 was available around each trash rack for paint and debris accumulation. It was conservatively assumed that one trash rack was operational, and that a minimum of half of the depth around both trash racks would be covered with debris other than paint. The assumption of 50% blockage is consistent with reference 3 and with the requirements of Regulatory Guide 1.82 Revision 0[10]. The requirements of Regulatory Guide 1.82 Revision 1 [6,8] states that calculations show that the accumulation of debris will not result in a loss of the available NPSH exceeding "50% of the NPSH requirements." By specifically applying the criteria of R.G. 1.82 Rev. 1, Comanche Peak is classed in criterion 3 since the flow velocity at the trash rack screens is less than .15 ft/sec for the unobstructed flow case, and the water level is above the trash rack sump screens. Thus, Comanche Peak, under criterion 3 possesses little or no potential for debris transport for the three major types of insulation, fibrous, reflective metal or closed-cell (encapsulated). This conclusion is further supported by NUREG-0897[9] which states that plants having large screen areas can tolerate large quantities of transported debris and that a 0.2 ft/sec flow velocity was required to initiate the motion of indiviual shreds of insulation. Comanche Peak's large trash rack area of 500 ft^2 and surface velocity of about 0.08 ft/sec verifies this conclusion since pool velocities far from the trash racks, although not specifically determined, will be smaller. Thus this study, with a conservative 50% debris blockage, will concentrate on paint effects alone. All paint was also assumed to accumulate as peels. Since the zinc primer paint would most likely disintegrate as a powder, this assumption is conservative with regard to trash rack clogging since a powder could flow through the trash racks and screens. The top of the trash rack is blocked and is unavailable for flow. Various quantities of paint peels were assumed to pile on top of the debris with packing ratios of 1.0 to 0.75 with no flow area available through the paint peels. Justification for the lower packing ratio of 0.75 is discussed later in this section.

The uncovered depth of the trash rack was computed in each case and the pressure drop due to a flow of 12500 gpm through this uncovered depth was

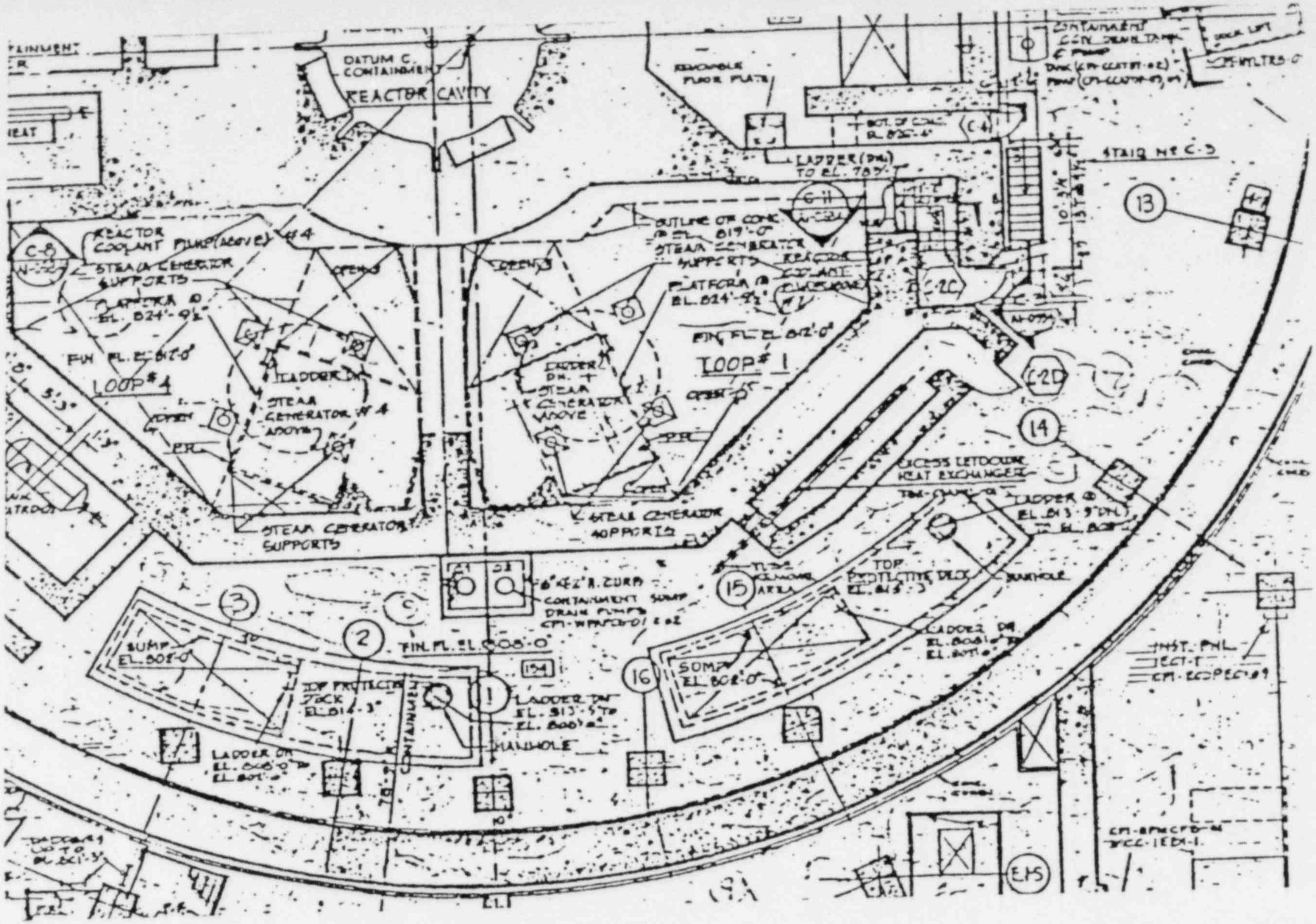


FIGURE 2

Area around the trash racks for debris and paint accumulation

Table II

No	Vol. of paint blocking the screen, ft^3	Vol. of debris blocking the screen, ft^3	Total blocked depth, ft.	Percentage screen blocked by debris	Percentage screen blocked by debris and paint	Δp, across trash rack, ft of water
1	1049.6	3125	4.175	50	66.8	0.025
2	1049.6	4541	5.59	72.6	89.5	0.25
3	1049.6	4967.7	6.02	79.5	96.3	2.0
4	1049.6	5053.4	6.10	80.8	97.6	5.0

Note: Percentage screen blocked = (depth of screen blocked x 100/6.25)

Packing ratio for the paint = 1.0

calculated. The pump performance would be adjudged not affected if this pressure drop were much less than the suction head of the pump (8'8"). The results for a packing ratio of 1.0 could be found in Table II. It is seen that the pump performance would be affected when the screen is blocked 90% and over. It was assumed in Case 1 of Table II, that half the depth of the screen is blocked by debris other than paint, and the total quantity of paint, 1049.6 ft^3, was assumed to stack on top of it. In cases 2 to 4, the volume of debris other than paint, was increased beyond the value in Case 1. It is seen with these assumptions that the pump performance would be affected when debris in excess of about 4000 ft^3 collected and the total quantity of the paint peels fill the space around the trash racks.

Realistically water will be trapped between the paint peels with the resulting packing fraction less than 1.0. Two least probable configurations for packing of the paint peels exist. As illustrated on Figure 3 they are:

(1) All peels packed tightly together with no water space between them.
(2) All peels packed in an alternate fashion to allow maximum amount of water between peels.

The first case represents a packing ratio of one where packing ratio is defined as the ratio of the volume of paint to the total water and paint volume. The second extreme represents a packing ratio of 0.5. The distribution of paint peels in the pool of water is a random process; therefore, it is appropriate to define the average packing of the peels as equal to the mean value of the two extreme cases. Consequently, it is appropriate to use 0.75 as the average mean packing ratio for the accumulated paint in the sump. Assuming water viscous effects would not appreciably affect the paint packing ratio, a packing ratio of 0.75 has been considered to obtain the pressure drop results in Table III. For conservatism no flow was assumed possible through the spaces in the occupied region. Even with this lower value of paint packing ratio, the conclusion regarding pump performance remains unchanged. That is the pump performance would be affected only if the total quantity of paint and debris in excess of 4000 ft^3 accumulate around the trash racks.

The spacing between paint peels is inversely proportional to the packing ratio. The average distance between stacked paint peels

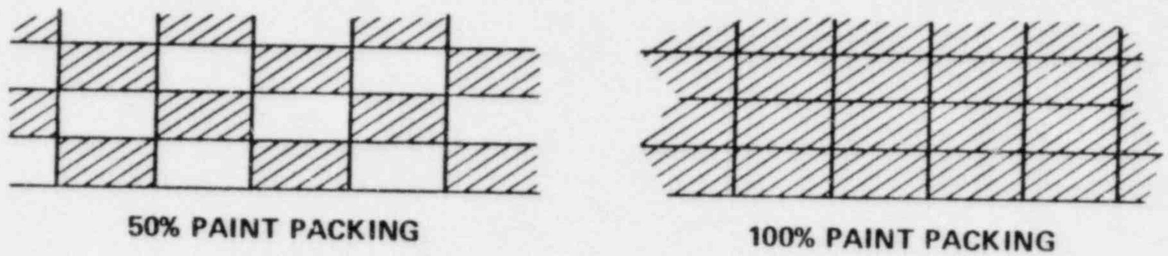


FIGURE 3

Paint Peel Packing Configuration

Table III

No.	Volume of paint blocking the screen, ft^3	Volume of debris blocking the screen, ft^3	Total blocked depth, ft.	Percentage screen blocked by debris	Percentage screen blocked by debris and paint	Δp, across trash rack, ft of water
1	1049.6	3125	4.52	50	72.3	0.037
2	1049.6	4192	5.59	67.1	89.5	0.25
3	1049.6	4618	6.02	73.9	96.3	2.0
4	1049.6	4704	6.10	75.3	97.6	5.0

Note: Percentage screen blocked = (depth of screen blocked x 100/6.25)

Packing ratio for the paint = 0.75

of thickness 0.035 inches with a packing ratio of 0.75 is 0.012 inches. Smaller packing ratio would result in larger spacing distances between paint peels. The larger spacing would permit water flow to reach the trash rack surface, thus, in effect, increasing the flow area to the trash rack screens. At a packing ratio of 0.5, the average spacing between the peels would actually equal the paint peel thickness. Thus the actual pressure drop through the trash racks would be expected to increase with decreasing packing ratio up to a maximum value at a critical packing ratio which would offer the largest resistance to flow. Then a decrease in value would occur for smaller packing ratios as more flow area became available between peels. Thus the pressure drop calculations in Table III for a 75% packing ratio and no flow area between peels can be considered conservative since in actuality the blocked paint height would contain about 25% flow area for water. An approximate method to estimate the actual packing ratio due to kinetic theory is contained in Appendix B.

3.2 Supplementary Analyses

It was conservatively assumed in Section 3.1 that all the containment paint accumulate in the area immediately around the trash racks and fill the space above the debris. Questions about the motion of the paint peels within the water and the ability of the peels to stick to the vertical trash rack surface are addressed here.

It is assumed here that only one sump is operative and half the depth around the trash rack is covered with debris other than paint. The screen presents a free flow area fraction of 0.7, that is 70% of the face area is available for flow and 30% is covered with metal. Paint peels incident normally near the screen surface would be pressed against the screen by the hydrostatic pressure. The weight of the peel tending to pull it down would be resisted by the friction between the paint peel and the metal surface. Calculations indicate that the friction is much higher than the weight of the peel and thus the peel would indeed cling to the surface of the screen vertically. It was estimated from the dynamics of vertically descending peels, that the peels incident on an area within about 2" of the screen surface could be pressed against the screens. Details of this estimation are described at the end of this section. For conservatism, 25% of the paint incident on top of the trash rack was added to this category. The resulting area blocked by vertically sticking paint peels was calculated to be approximately 72 ft^2; this area corresponds to a depth of about 0.9'. Since half the depth is already assumed blocked by debris, the total depth blocked is now 4.025'.

The suction to the ECCS pump will now pass through the remaining available depth of 2.225'. The flow stream lines would be normal to the screen surface near the trash rack. Paint peels falling elsewhere in the pool at different angles of incidence, would be transported under the water velocity, gravity and drag to the screen subject to buoyancy and other effects.

They would ultimately tend to align themselves with the stream lines. It was estimated that the peels at an average distance of 24 ft from the screen could be transported to the vicinity of the surface of the screen. Details of the estimation can be found at the end of this section. This distance corresponds to an area about 922 ft^2 surrounding one operating trash rack. If all the containment paint peels block the trash rack in addition to the already blocked depth of 4.025' with a packing ratio of one and no flow assumed through the paint, a further height of 1.14' would be blocked, leaving a height of 1.08' for flow. The pressure loss would be equal to 0.09', corresponding to a blockage of about 83%. Thus the pump performance would not be affected. The blockage of the trash rack occurs due to two processes: (1) peels sticking vertically which will be called adhesion and (3) peels accumulating in the surrounding volume which will be called accumulation. If the entire paint blocked height due to paint peel adhesions and accumulation were made available to paint accumulation,for the 4.025' blocked height, a packing ratio of 0.56 would result which is close to the lower limit packing ratio. Thus the conservatism of the above assumptions is justified. Additionally, calculations indicate that the flow velocity on top of the paint is insufficient to lift it due to a venturi effect.

<u>Estimation of the distance 2" from the surface of the trash rack, for vertically clogging peels</u>

Referring to Fig. 4, the trash rack has a height of 6.25'. Half this depth, equal to 3.125', is assumed filled with debris. The flood water level is assumed to be 20' above the base of the trash rack or 16.875' above the surface of the debris. The hydrostatic pressure due to this head of water equals 1051.3 lbf/ft^2. Referring to Fig. 5, showing a peel pressed against a typical grid, a unit grid area of 1 ft^2 can be considered. Since the blockage factor is 0.7, the metal area is 0.3 ft^2. and the balance, 0.7 ft^2, is flow area. The hydrostatic pressure will tend to hold the peel against the screen. The metal area would offer a reaction. The weight of the peel would tend to pull it down against the frictional force offered by the bearing surface. If the frictional force were higher than the weight, the peel would cling to the surface of the screen vertically.

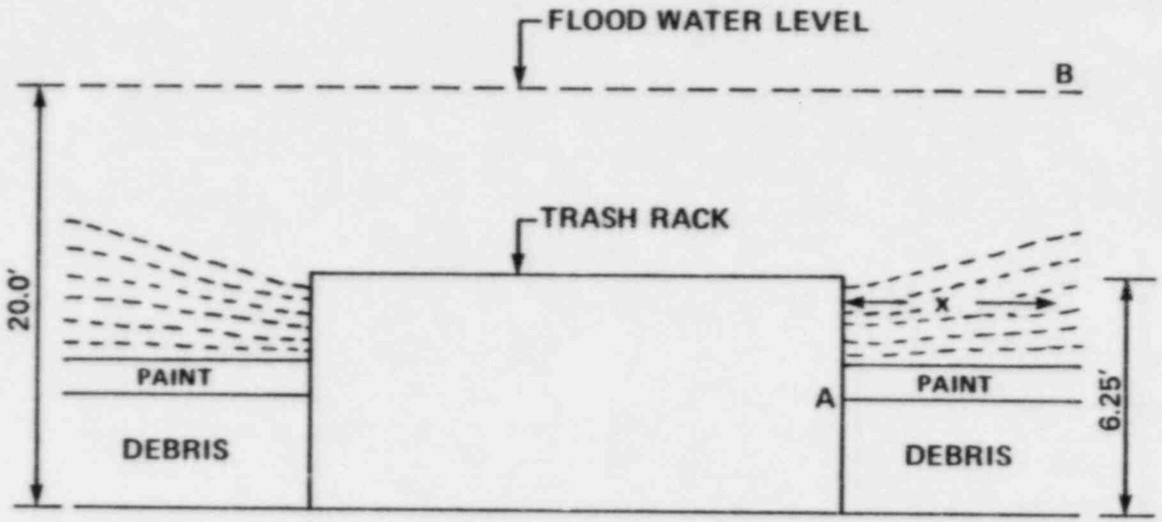


Figure 4

Trash Rack Elevation View

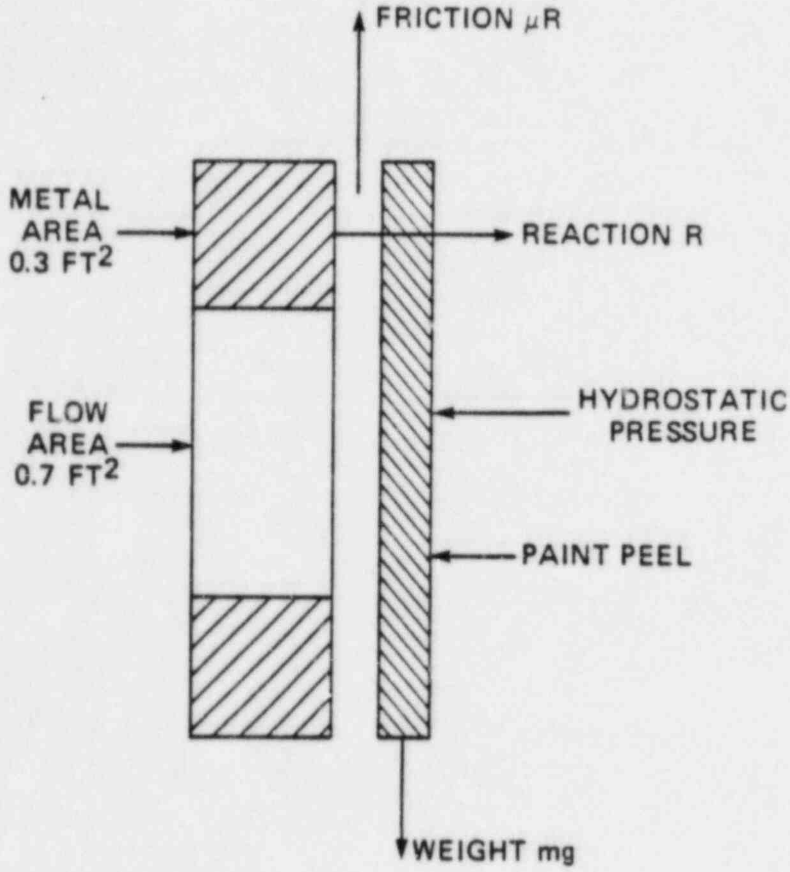


Figure 5

Paint Peel Adhesion to the
Trash Rack Screens

The reaction at the metal surface equals 1051.3x0.3, or 315.4 lbf. Assuming a coefficient of friction of 0.1, the frictional force equals 31.54 lbf. The peel of area 1 ft^2 and thickness 0.03" weighs 0.2 lbf. Hence, the peel would indeed cling to the surface of the screen vertically.

Using Fig. 4, Consideration will be given to a vertical peel striking the water surface at a horizontal distance of x from the trash rack. It will be conservatively assumed that the incident velocity equals zero. Since the drag on a vertically descending paint peel is small and negligible, the time t taken by the peel to fall through a distance of 16.875' is given by $\frac{1}{2} gt^2$ = 16.875 and is found to be 1.02 sec. While the peel descends vertically, it would be transported to the screen by the velocity of the water. The water velocity is 0.161 ft/sec at the screen and it reduces with distance. It is conservatively assumed that the water velocity is a constant equal to 0.161 ft/sec and that the peel is transported without slip. The distance x is then equal to 0.161 t which is about 2" with t equal to 1.02 secs. Thus, the paint peels incident within 2 inches of the trash rack could be expected to clog the screen vertically.

<u>Estimation of the distance of 24' from the trash rack regarding peels incident on the surface of the water at different angles:</u>

Figure 6 illustrates a paint peel at an angle θ to the vertical moving under water. The weight mg acts vertically downwards. The reaction R acts normal to the surface. The peel would fall down under the influence of mg opposed by R Sinθ; at the same time, the component R cos θ would tend to push the peels towards the trash rack subject to drag in the horizontal direction. The equation of motion in the vertical and horizontal directions are:

$$m \frac{du}{dt} = mg - R \sin \theta$$

$$= mg - C_D/2 \, u^2 A \cos \theta \, \rho_w$$

$$m \frac{dv}{dt} = R \cos \theta - C_D/2 \, A \sin \theta \rho_w (v-v_o)^2$$

Where, m = mass of the peel = ρ_p Aw

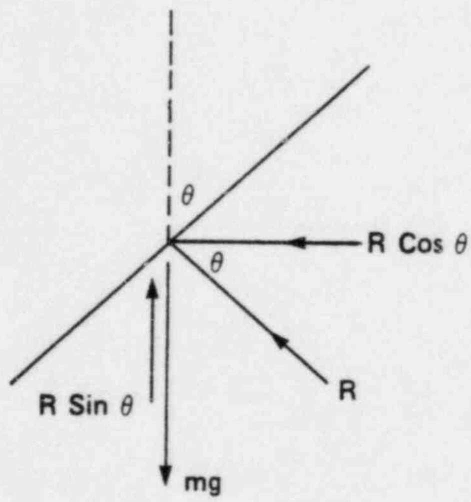


Figure 6

Paint Peel Force Model

ρ_p = density of the peel

A = Area of the peel

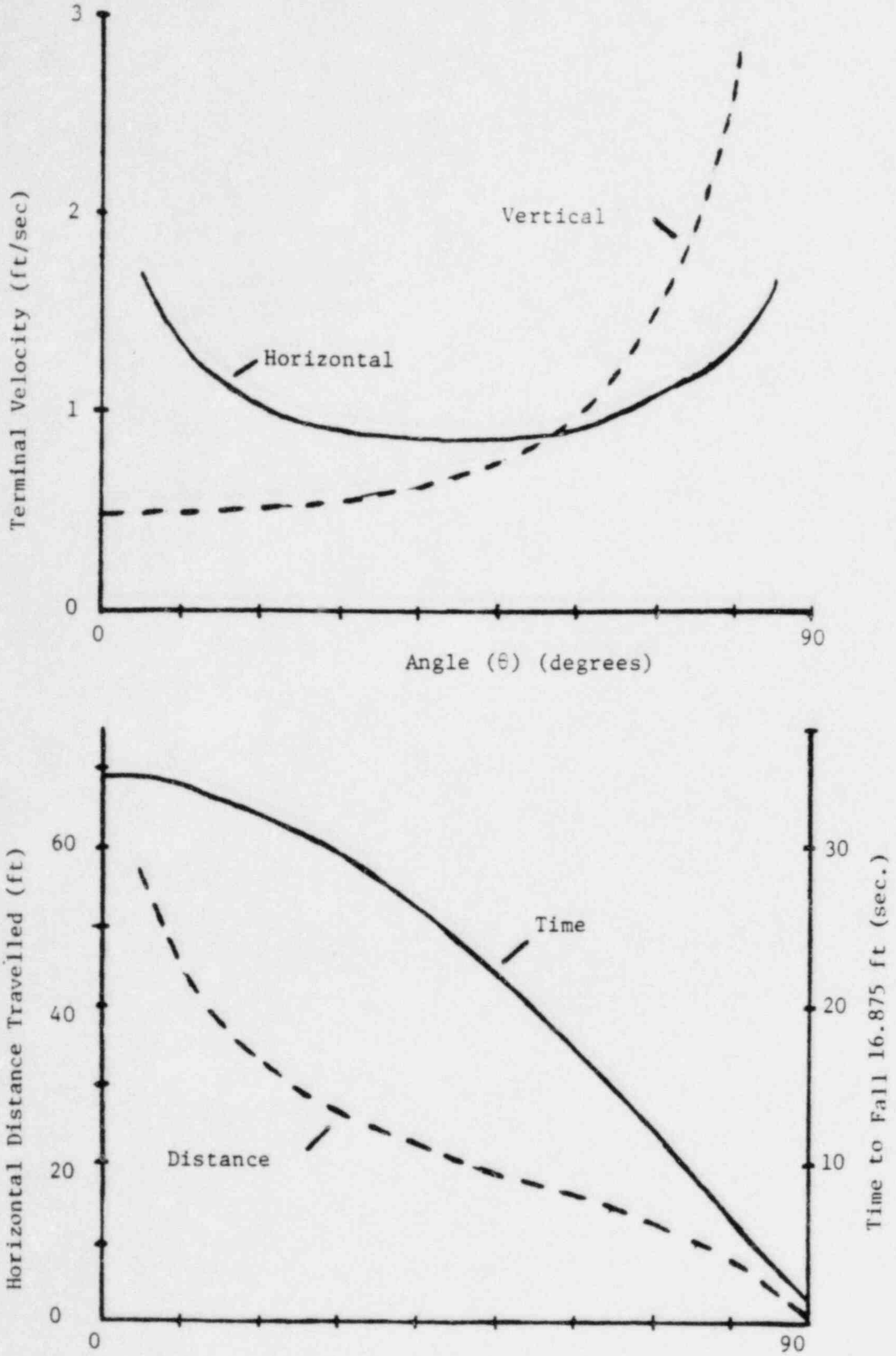
w = Thickness of the peel

C_D = drag coefficient

ρ_w = density of water

v_o = pool water velocity

The vertical terminal velocity for any angle θ is obtained by setting $m \frac{du}{dt}$ equal to zero. An angle of zero would result in the longest vertical travel time. This furthest horizontal tragel occurs at the angle for which the value of the multiplication of the horizontal velocity and the vertical travel time is largest. As seen from Figure 7, the longest travel time occurs at a small angle. However, the equations used to model the paint peel fall are inaccurate at angles near zero and ninety degrees since boundary layer effects on drag have been ignored in the equations. Consequently, results at angles greater than 85° and less than 5° are not considered to be representative of actual conditions. Despite these assumption problems, the average horizontal travel distance for any paint peel can be calculated to fall betwe‹n 22 and 24 feet using the information presented in Figure 7.



3
2
1
0
Terminal Velocity (ft/sec)
Vertical
Horizontal
0
90
Angle (θ) (degrees)
60
40
20
0
Horizontal Distance Travelled (ft)
30
20
10
Time to Fall 16.875 ft (sec.)
Time
Distance
0
90
Angle (θ) (degrees)

Figure 7

4. Conclusion

It is estimated that the performance of the ECCS pumps would not be adversely affected, if the trash racks were blocked 83% or less. The pressure loss across the trash rack due to a blockage of 83% is much less than the normal suction head of the pump. Such a blocking limit would be reached if (1) debris exceeding about 4000 ft^3 fill the space around the trash racks, in addition to the total quantity of paint filling the same space with a packing ratio of 0.75 or, (2) if the entire quantity of paint fills the space around one trash rack with some of the paint peels clogging the screen vertically, in addition to debris covering half the trash rack depth. Since the accumulation of all the paint inside containment plus the assumption of having half the trash racks blocked with debris is insufficient to exceed 83% blockage, ECCS performance is not considered capable of being affected by trash rack clogging.

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Appendix A

Partial Report of

Western Canada Hydraulic Laboratories LTD.

Regarding

Model Testing of the Recirculation Containment Sump

COMANCHE PEAK STEAM ELECTRIC STATION
UNITS 1 AND 2

MODEL TESTING OF
THE RECIRCULATION CONTAINMENT SUMP

FOR
TEXAS UTILITIES SERVICES INC.

BY
WESTERN CANADA HYDRAULIC LABORATORIES LTD.
PORT COQUITLAM, B.C.

73044

NOVEMBER, 1981

1.0 PURPOSE OF STUDY

The purpose of the hydraulic model studies was to test and modify, if necessary, the Recirculation Containment Sumps and Intakes of the Comanche Peak Steam Electric Station, Units 1 and 2, and demonstrate that the accepted design would not be subject to vortices or other hydraulic phenomena that would degrade their performance or produce adverse effects on the ECCS pumps. The tests also measured an intake headloss for each intake to demonstrate that intake head losses were within the design value for the plant, and measured head losses across trash racks and screens.

2.0 INTRODUCTION

The U.S. Nuclear Regulatory Commission in Regulatory Guide 1.79 states that "A comprehensive preoperational test program on the Emergency Core Cooling System and its components should be performed to provide assurance that ECCS will accomplish its intended function when required". Furthermore, "the (preoperational) testing should include taking suction from the sump to verify vortex control and acceptable pressure drops across trash rack with screens and in valved suction lines", and "the testing should verify that the available net positive suction head is greater than that required at accident temperature."

A satisfactory in-plant test of the Comanche Peak Steam Electric Station Units 1 and 2 was not feasible due to logistical problems of flooding the containment and the lack of access to the sump for observation to ensure proper vortex control.

The alternative, as presented in this report, was to construct and test models of the sumps and intakes to verify vortex control and to determine the headlosses associated with the trash rack, screens and pipe inlets.

Tests for the Comanche Peak Units 1 and 2 recirculating intakes were carried out on a 1:1 scale model of a pair of 16 inch diameter intakes and their containment sump and trash rack structure at flows rates greater than maximum postulated values and at water depths equivalent to the minimum postulated levels. The containment geometry and all significant items in the vicinity of the trash rack were also modelled. Model tests undertaken for the Davis Besse, J. M. Farley, ANO-2, San Onofre, Midland and Palo Verde nuclear plants have demonstrated the effectiveness of a suitably-placed grating cage in preventing the development of adverse flow conditions which could lead to degrading effects on pump performance. The effectiveness of a similar grating cage on the Comanche Peak Units 1 and 2 intakes was demonstrated during these tests.

The rationale for the test program is presented in this report together with a description of the intakes, a discussion of effects which could degrade pump performance, a description of the test facility, the testing program, test results and conclusions.

3.0 SUMMARY AND CONCLUSIONS

3.1 The recirculation intakes for Comanche Peak Units 1 and 2 were tested using a 1:1 scale model of a pair of intakes and their sump and trash rack. The model was tested under the following conditions:

	Postulated For Plant LOCA	Tested
Minimum water depth above sump floor	8' 8"	8' 1" - 9'1"
Max flow-one intake operating	7,200 (CS) 5,300 (RHR)	12,348 8,651
Max flow-both intakes operating	12,500	19,582
Water temperature °F	247	44-177
Intake pipe Reynolds No.	5.82×10^6 (CS) 4.28×10^6 (RHR)	From 1.05×10^6 to 5.25×10^6 (Both CS and RHR)
Blockage of screen area, percent	50	90+

3.2 The results of the tests on the single sump are applicable to all four sumps (two each in Units 1 and 2) because of their similar geometry, flow rates and depths of submergence.

The differences between train A and train B sumps in each unit are as follows:

1) The trash rack frame on train A sump in each unit is of heavier construction than that on train B sump. There are internal braces on the train A sump trash racks which reduce effective screen area, and hence increase approach flow velocities. In addition these braces are a potential source of flow disturbance.

2) The trash racks on train A sumps are also marginally smaller and are asymmetrical. Trash racks on train B sumps are symmetrical about a radial axis through the center pair of columns of the trash rack.

The model configuration is that of the train A sump and the surrounding containment area in Unit 2. This is a mirror image of, and hence hydraulically identical to, the train A sump in Unit 1. This model configuration was chosen because:

i. the optimum arrangement within the test facility for testing and observation could be attained;

ii. the trash rack is smaller with heavier and more numerous support members. and thus more likely to generate poor hydraulic conditions within the sump.

Following the completion of tests on train A sump, the containment area adjacent to train B sump was modelled, retaining the more conservative train A sump trash rack. A series of sensitivity tests was carried out to establish any effects due to these changes. Further sensitivity tests were carried out by placing a superfluous 6 in. H-beam in the vicinity of the sump to delineate the effect, if any, of additional structural members.

3.3 Severe cavitation occurred at the lip of each intake when tested with the original design, ie with the intake pipe cut off at 56° to the pipe axis. This cavitation was eliminated by adding a 20° cone to each intake. (See Section 9.2.2 and Figure 10).

3.4 The tests showed that without the grating cage in place, air-entraining free surface vortices as well as vortices originating from the sump walls occurred even without trash rack blockage. Large free-surface vortices could also be produced by various combinations of screen blockages. No vortices developed under any tested conditions when the intake was protected by a suitable grating cage.

3.5 The trash rack and screen loss was found to be less than 0.021 ft at a prototype total discharge of 12,500 gpm.

3.6 The maximum intake head loss coefficient measured with the grating cage in place and 50 percent blockage corresponded to a loss of 0.52 ft for a prototype discharge of 7,200 gpm.

3.7 A separate series of tests under a variety of 50% blockage conditions, designed to establish the mean intake loss coefficient and the 95 percent confidence interval, can be summarized as:

	Prototype flow rate gpm	95% Confidence Limits 50% blockage
Intake 1	5,300	0.153 ft < head loss < 0.175 ft
Intake 2	7,200	0.102 ft < head loss < 0.126 ft
Trash rack and screens	12,500	0.011 ft < head loss < 0.011 ft

3.8 The sensitivity tests showed that no significant effect on head losses or vortex action occurred with a substantially altered containment configuration or the inclusion of a superfluous structural member.

3.9 The effectiveness of the grating cage in providing vortex control was demonstrated repeatedly.

4.0 DESCRIPTION OF CONTAINMENT SUMPS AND INTAKES

Each unit of the Comanche Peak plant contains two recirculation sumps located on the west side of the building. The sump configuration of Unit 2 is a North-South mirror-image of that of Unit 1. (See Figure 1).

Each sump is 5'5" in width and 6'0" deep, and subtends an angle of 14° 50' to the containment centerline. The side walls of all four sumps are arcs with radii of 54' 11" and 60' 4", and the end walls are radial to these arcs.

Two intakes are located on the outer wall of each sump, with their centerlines 4°45' each side of the radial axis of symmetry. One intake in each sump supplies the CS pumps and the other supplies the RHR pumps. These intakes draw 7200 gpm and 5300 gpm respectively. However the intakes themselves are identical.

The trash racks are asymmetrically located with respect to the sumps, and their construction differs between the two sumps in each unit. The trash racks on train A sumps carry pipe supports and seismic restraints, and have additional internal bracing. The spacing of the columns is also asymmetrical on these trash racks. Trash racks on the train B sumps are lighter in construction and have columns regularly spaced at intervals of 7°30'.

The trash rack bars and coarse screens are mounted in frames made of steel angle, and these in turn are bolted to the outer faces of the trash rack columns. The fine screens are mounted in separate frames of steel angle and flat bars which are bolted to flanges extending from the central web of each column.

The trash rack bars are 5/16" diameter, at 4-5/16" O.C. Due to manufacturing and supply problems, a number of changes were made to screen specifications during construction of both model and prototype. These are reflected in the following table:

	COARSE SCREEN	FINE SCREEN
Specified By Client	.500 in. Sq. Openings .105 in. Dia. Wire 68.3% Open Area	7 Mesh .020 in. Dia. Wire .123 in. Wide Openings 74.1% Open Area
Trash rack Supplier	2 Mesh 14 GA. Wire .420 in. Wide Openings 70% Open Area	7 Mesh .028 in. Dia. Wire .115 in. Wide Openings 64.6% Open Area
Test Model	.500 in. Sq. Openings .105 in. Dia. Wire 68.3% Open Area	7 Mesh .028 in. Dia. Wire .115 in. Wide Openings 64.6% Open Area

Since most of the screen head losses occur across the fine screen, the slight difference in coarse screen size is not expected to be significant. In any case, this difference on the model will tend towards more conservative estimates of screen losses.

WCHL constructed its trash racks with the horizontal bars laid over the top of the vertical bars. On the prototype trash racks, the supplier interwove these bars. This difference is not significant in terms of the validity of test results.

Appendix B

Paint Packing Ratio Estimation

Estimation of the Packing Ratio Under Static Conditions

By considering the accumulation of an ideal uniform stack of paint peels with a packing ratio of one without separation and an average thickness t=0.03", 400 peels would exist in a one foot depth. In reality however, molecular forces will result in producing a separation between the peels, varying with the depth of water and weight of peels above the point of consideration. If the number of peels from the surface of the water to a particular depth is defined as n, the downward force (F) on the water at the considered depth could be computed as the difference between the weight of the peels and the buoyancy on the peels.

The area of a peel of width b and depth d is, A = bd. Therefore, the resultant force is:

$$F = n\,A t \rho_p - nA\,t\,\rho_w$$

$$= n\,A\,t\,(\rho_p - \rho_w)$$

The pressure due to this force is computed by $F/A = nt\,(\rho_p - \rho_w)$. Since the fluid is assumed static, the pressure is the same in all directions. The resultant force in the horizontal direction is equal to $nt\,(\rho_p - \rho_w)r\,d$ for a <u>small</u> separation (r).

This force is balanced by the molecular surface forces between the water and the peel which decrease with increasing separation r. These forces act on the two bounding paint surfaces. These surface forces are expressed in units of force per unit length σ. In FPS units, σ will have the dimensions of lbf/ft.

This force is balanced by the total hydrostatic force. Therefore,

$$n\ t\ (\rho_p - \rho_w)\ \ r\ d = 2\ b\ \sigma$$

$$r = \frac{2\ \frac{b}{d}\ \ \sigma}{nt\ (\rho_\rho - \rho_w)}$$

In the above equation b,d and t are in dimensions of length, σ has units of force per length, n is the number of peels, ρ_p and ρ_w are the weight densities of the paint peel and water with the dimension of Force/(Length)^3 When square peels are considered,

$$r = \frac{2\sigma}{nt\ (\rho_p - \rho_w)}$$

The surface-fluid interface constant σ for water and paint peels is not known precisely. However, σ for air interface is 0.005 lbf/ft. (Ref. 7). Adamson (Ref. 11) reports values of 72 dynes/cm ((0.0049 lbf/ft.) for water air interface; he also reports values as low as 20 dynes/cm (0.00137 lbf/ft) for interfaces between water and certain surfaces. The packing ratio may be defined as the ratio of the height of vertically stacked paint peels without separation and the height with separation. The packing ratios were found to be 0.31 and 0.39 with σ's equal to 0.0049 and 0.00137 lbf/ft. respectively. The separations calculated for the first 10 peels were found to be high, thus the assumptions made in the derivation of the separation distance calculated by this method may not be valid. Hence, the packing ratios were also calculated omitting the first 10 peels. The packing ratios were found to be 0.39 and 0.76 with σ=0.0049 and 0.00137 lbf/ft. respectively. Thus the packing ratios could be expected to range up to 0.76.

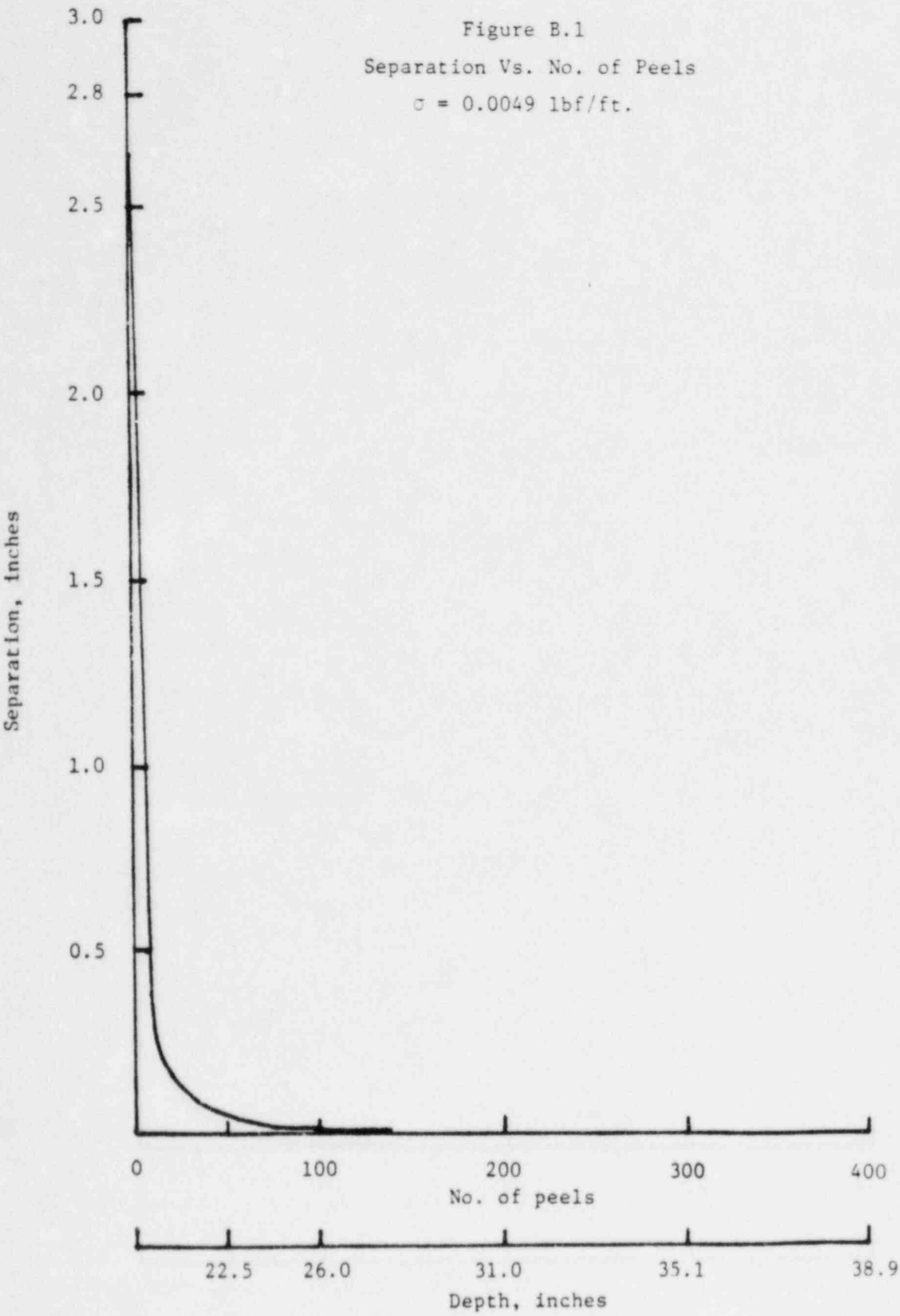
Figure B.1
Separation Vs. No. of Peels
σ = 0.0049 lbf/ft.
3.0
2.8
2.5
2.0
1.5
1.0
0.5
Separation, inches
0
100
200
300
400
No. of peels
22.5
26.0
31.0
35.1
38.9
Depth, inches