EVALUATION OF VORTEX FORMATION IN TANKS AND SUMPS

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INTRODUCTION

The formation of vortices has always been a concern to hydraulic engineers. Water for pumps that support systems in power plants and other industrial applications is typically draw from a free surface water source. Studies have shown that vortex entraining 1 % (by volume) of air can cause as much as a 15 % reduction in the efficiency of a centrifugal pump. In extreme cases, where 10 % entrained air in the fluid stream could cause significant damage to the pump. This is an economical consideration for commercial facilities that do not support a critical need, but for facilities that require pumps that are critical for safe operation, i. e., hospitals, chemical plants and nuclear power plants, the failure of a pump due to the formation of vortices could lead to disastrous consequences. Recently, a renewed interest has occurred concerning vortex formation in tanks at nuclear power stations. In several nuclear regulatory commission (NRC) inspections, inspectors questioned the specific use of the vortex correlation that defined the critical submergence. Additionally, operating plants continue to experience vibration problems due to vortex formation at the intakes of circulating water pumps.

DESCRIPTION OF WORK

Many studies have been performed to assess the height of fluid (i.e., submergence) that is required to ensure that vortices do not occur. This submergence level is dependent on many variables including fluid surface tension, viscosity and velocity of the fluid leaving the tank, density of the fluid, geometry of the inlet. Some studies suggest that vortex formation is chaotic and random and can not be predicted consistently (Ref. 1). Other studies suggest that the submergence can be predicted based on Froude Number and the exit pipe diameter (Refs. 2 and 3). While others suggest that the Reynolds Number determines submergence height. Significant research has been conducted with each experiment producing a different vortex formation correlation. This work assesses all relevant data and vortex formulations (Refs. 1, 2, and 3) and presents a sound vortex formation correlation that can be applied to consistently predict the critical submergence.

It is imperative that the vortex formulation used is conservative enough to protect the pumps, but not overly conservative where the requirements prohibitively restrict operation flexibility and contribute to excessive increase cost. The evaluation presented here was performed to assess the empirical and theoretical composition for vortex formation and to develop a conservative correlation based on the available information. Over 15 methods were reviewed and compared to empirical data.

RESULTS

The results showed that many of the correlations were very conservative and some of the correlations were not conservative enough. From these evaluations and analyses, a vortex formation correlation was proposed that provided adequate margin of conservatism and maintained operation flexibility. The correlations developed are based on submergence height, exit pipe diameter and the velocity of the fluid leaving the tank. The correlations are presented below.

FOR TANKS

Some Recirculation

$S_c = D \times 2.77 \times (V_c/(g \times D)^{1/2})^{1/2}$

No Recirculation

$S_c = D \times 2.1 \times (V_c/(g \times D)^{1/2})^{1/2}$

FOR TANKS AND SUMPS

Significant Recirculation

$S_c = D \times (1.0 + 2.3 \times (V_c/(g \times D)^{1/2})$ Flow<7500 gpm

$S_c = D \times 5.6 \times (V_c/(g \times D)^{1/2})^{1/2}$ Flow>7499 gpm

Where

S_c = Critical Submergence, feet

D = Inside Diameter of outlet pipe, feet

V_c = Velocity of water in inlet pipe, feet

These correlations should be used to determine the critical tank or sump level to prevent vortex formation.

REFERENCES

1.0 Regulatory Guide 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems," Appendix A, "Guidelines for Review of Sump design and Water Sources for Emergency Core Cooling," (1983).

2.0 Jost Knauss, "Swirling Flow Problems at Intakes," Technical University of Munich, Obernach, FR Germany, (1987).

3.0 A. K. Jain, et al., "Vortex Formation at Vertical Pipe Intakes," Journal of the Hydraulics Division, Vol. 104, No. HY10, (October 1978).