DESCRIPTION OF SURFACE VORTICES WITH REGARD TO COMMON DESIGN CRITERIA OF INTAKE CHAMBERS

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Summary

In a model testrig with easy to change geometrical shape, an investigation of seven different configurations of intake chambers was conducted. These configurations were taken mainly from existing layouts. The observed surface vortices were documented and compared to layouts of commonly accepted recommendations.

By the choice of one of the listed layout recommendations of HIS, BHRA or Padmanabhan, the strength of the potential vortices in the intake chamber can be influenced. The Padmanabhan design is guided along a more conservative layout of the intake structure.

All the documented configurations, which can be plotted in the recommended spectrum of submergence, show maximum vortices of type 2. The examined variations, which are located within the recommended range of S/D of HIS and BHRA brought on vortices of type 4.

So at the first design stage of a new intake chamber for power plants, it is possible by following one of the mentioned recommendations to achieve an intake chamber layout which is positioned more closely to potential vortices of type 2 or 4 according to the Hecker scale.

In any case, the choice of the respective layout should ensue in conjunction with the local preconditions and the required safety in operation, so that model tests seem to be advisable.

1. Introduction

To satisfy the ever increasing demand for energy, conventional and nuclear power plants are used. In recent years, both types of power plants show a strong tendency to bigger block capacities.

On average, the production of one megawatt of electrical power needs 144 $m^3 h^{-1}$ of cooling water. The heat emission depends on the thermal efficiency of the power plant. Today, conventional power plants reach a thermal efficiency of 40-42 per cent, that means about 60 per cent of the energy has to be carried off with the cooling water.

Depending on the increase of the block capacity and the tendency to use a smaller number of pumps, the development has focused on bigger pump units.

The performance of these big pump units requires a proper hydraulic design of the intake chamber. The intake chamber is situated immediately upstream of the cooling pump. It allows an approach flow towards one or more pumps which is evenly flow-balanced on all sides and is free of large turbulences.

Such a smooth flow is the precondition for an overall uncritical working of the pumps. Poor hydraulic design of a pump sump and intake could arise because of insufficient attention at the early design stage. Possible consequences are, for example, pump disturbing pre-swirl, noise and undefined vibrations or in the worst case air entraining surface vortices, which could lead to a total loss of the cooling pump.

Additionally, the change of the operating conditions, e.g. low water levels in a hot summer or a non-uniform approach flow caused by an emergency or an obstructed screen must not endanger the efficiency or the security of the power plant.

To prevent late and therefore expensive modifications on a newly built intake chamber, model tests are generally considered necessary in the design of large plants or those with particular difficulties, e.g.

- Non-uniform approach flow.
- Extremely low water level.
- Multiple pumps with one common approach channel.
- Modifications of older structures caused by an increasing demand for cooling water.
- Additional water supplies.

In principle, the numerical modeling of intake chambers is possible, but model tests remain essential, especially for complex situations.

The transferability of the results in these model tests is ensured if the flow in the model and the one in the original structure are "similar". That means a geometrical and hydromechanical similarity, according to the relevant similarity laws, must be given. The geometrical similarity is represented by the model scale $m_l = l_M/l_O$. Where the section of the intake chamber is covered, the flow is mainly influenced by friction and

turbulence and is characterized by the Reynolds number, which, in model tests, should be above a minimum value.
The Reynolds number is defined by:

$$Re = \frac{v_D \times D}{\nu}$$

v_D = flow velocity in a characteristic cross-sectional area.
D = diameter of the characteristic cross sectional, e.g. the pump bell diameter (see Figure 1).
ν = kinematic viscosity.

If the flow in the section under investigation is uncovered (free surface), the Froude law has to be fulfilled with first priority. That means, that the ratio of the force of gravity and the inertia force in the model have to be identical to those of the full-scale design.

The Froude number is defined by

$$Fr = \frac{v_D}{\sqrt{g \times D}}$$

g = gravitational constant.

For physical reasons, it is not possible, except in the trivial case of model scale 1:1, to fulfill the Reynolds and the Froude number at the same time. Because most intake chambers are designed as uncovered structures, the Froude numbers between the model and the full scale plant should be equal. Nevertheless, Reynolds cannot be neglected.

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Bibliography and Suggestions for further study

Domm U, Rosemann P and Siekmann H (1973) Modelluntersuchungen der Einlaufkammerströmung einer großen Kühlwasserpumpe, KSB Technische Berichte No. 16, Frankenthal.

Gehrer, A., Benigni, H., Köstenberger, M.(2004), "Unsteady Simulation of the Flow Through a Horizontal-Shaft Bulb Turbine", Proceedings of the 22nd IAHR Symposium on Hydraulic Maschines and Systems,Stockholm, .

Gehrer, A., Egger A., Riener J.(2002), "Numerical and Experimental Investigation of the draft tube flow downstream of a bulb turbine", Proceedings of the 21st IAHR Symposium on Hydraulic Machines and Systems, Lausanne, September 9-12, .

Hecker G E (1987) Fundamentals of vortex intake flow, Swirling flow problems at intakes, IAHR Hydraulic Structures design manual.

Hydraulic Institute Standards (1983) *Centrifugal, Rotary and Reciprocating Pumps*, 14th edition. Cleveland, Ohio.

KSB (1990) *Centrifugal pump lexicon*. 3rd edition, Holzenberger K. and Jung K (technical editors). Aktiengesellschaft, D-6710, Frankenthal, Germany.

Migod A and Siekmann H (1977) Einfluß von Kühlverfahren und Zulaufbedingungen auf die Bauart von Kühlwasserbedingungen für Wärmekraftwerke, KSB Technische Berichte No. 17.

Nakato T (1993) *Field-Tested Solutions to Pump Vibrations*, 1st International Symposium of Pump Noise and Vibrations, France.

Nakato T, Rosenberger H and Ettema R (1996) Inverted Draft Tubes to Improve Suction Performance of Vertical Pumps, EPRI TR-106266 3456-01 Final Report.

Padmanabhan M (1987) Design recommendations, Chap. 6.2 Pump Sumps, Swirling flow problems at intakes, IAHR Hydraulic Structures design manual.

Pfleiderer C (1955) *Die Kreiselpumpen für Flüssigkeiten und Gase*. Springer Verlag, Heidelberger Berlin Germany.

Prosser M J (1977) The hydraulic design of pump sumps and intakes, BHRA/Construction Industry Research and Information Association.

Rosenberger H, Hellmann D-H and Grasmück G (1996) *Investigation of Sewage Plant Intakes*, International Symposium on Fluid Machinery and Fluid Engineering, Beijing, China, September 9-12, 1996.

Ruprecht, A., Maihöfer, M., Heitle M., Helmrich, T.(2002), "Simulation of vortex rope in a turbine draft tube", Proceedings of the 21st IAHR Symposium on Hydraulic Machines and Systems, Lausanne, September 9-12,

Tillack P, Hellmann D-H (1996) *Model Studies of the Intake Structure of Cooling Water Pumps: HKW Würzburg and DIDCOT B*, Proceeding of the 4th International Symposium on Natural Draught Cooling Towers, Kaiserslautern, Germany.