Chapter 6
Overflow Gates:
Nappe Oscillations and Vibrations

ABSTRACT

This chapter focusses on instabilities associated with overflowing gates -- nappe oscillations and flap gate vibrations. A detailed mapping of potential initiating and sustaining energy sources is developed to help understand the mechanism of nappe oscillations. The precise mechanism of nappe oscillations remains an unsolved problem in fluid mechanics, even though we understand the process well enough to provide effective countermeasures to prevent nappe oscillations. We do not yet have the ability to definitively predict the onset criteria for nappe oscillations nor can we predict which mode of nappe oscillations will predominate and what produces changing modes with changing flow conditions. A method of determining added mass and in-water vibration frequency of flap gates is presented at the conclusion of the chapter.

INTRODUCTION

Decisions concerning the selection of gate types at any particular site are complex, and must take into account technical economic, environmental, and even aesthetic requirements. Erbisti (2004) lists specific factors to consider:

- Reliability of gate operation
- Weight of the structure
- Simplicity of operation
- Ease of maintenance
- Complexity of ancillary structures
- Magnitude and direction of hydraulic loads
- Required capacity of hoist motor
- Challenges of transport and on-site erection

DOI: 10.4018/978-1-5225-3079-4.ch006
Erbisti also notes, however, that there is no established routine method, or flow chart with a checklist, that leads consistently to the same choice. Experience and the expertise of the designers are often deciding factors in gate selection. Previous selection of a particular gate in a similar situation carries great weight in the decision.

Generally, gates specifically designed for overflow include flap, bear trap, drum and sector gates, as well as vertical-lift, fixed-wheel gates with hook-type crest structures (also called leaf gates). Inflatable rubber gates constitute another class of gates designed for overflow. Certain other gate types, such as long-span gates with a flap, Tainter/radial gates (called segment gates by Erbisti), as well as roller gates, all may be configured for overflow.

There are usually very good reasons for selecting an overflow gate as the control structure. Certainly, the gate must deliver the specified discharge capacity and regulate water surface levels. Almost as important, for most overflow gates, is the ability to pass floating debris and ice. Furthermore, the thin water curtain passing over the weir or gate, called the nappe, must be aerated to avoid flow-induced vibration and noise. Aeration can be achieved either by installing venting ducts or by adding spoilers (also called splitters, nappe breakers, or flow dividers) along the gate crest. The addition of spoilers in the design stage or as a retrofit when aeration is insufficient to attenuate flow-induced vibrations and/or tonal noise resulting from nappe oscillations carries an added maintenance cost. Although properly designed spoilers effectively attenuate nappe oscillations, they require cleaning to avoid accumulation of debris on the spoilers. Decisions to use spoilers instead of venting ducts may be based on construction costs. Depending on the amount of floating debris and how often debris has to be cleared from the spoilers, however, the cost of gate maintenance and debris removal may be higher than initially expected.

In other cases, certain gates are designed for simultaneous over- and underflow. Even when such gates have been specifically designed for either just overflow or just underflow, they may be used, sometimes unavoidably, for simultaneous over-and underflow. Details of gates with simultaneous over- and underflow can be found in Chapter 7 – Flow-Induced Vibration of Long-Span Gates.

In this chapter, we will consider flow-induced vibrations of overflow structures. We will review the mechanism of nappe oscillation and present several nappe oscillation countermeasures. Because flap gates have a propensity to vibrate, we will review several studies on this topic. Finally, we will present a method of estimating added mass for overflow gates, which provides a means of calculating natural frequencies of overflow structures.

OVERFLOW GATES

Flap Gates

Figure 1 shows schematics of several types of flap gate. Bottom-hinged flap gates (Figure 1a) are commonly used in irrigation systems, as weir or crest gates, and occasionally mounted atop vertical-lift or Tainter gates to permit passing of surface debris. A torque-tube flap gate (Figure 1b) consists of a tube with a rigidly connected gate structure. The actuator (often a hydraulic piston) drives the torque-tube to position the gate. Another variant of the flap gate is the fish-belly gate (Figure 1c), which also has a driving apparatus (not shown) similar to that of the torque tube gate. The “fish-belly” shape on the downstream side of the gate provides greater rigidity. The bear-trap gate in Figure 1d allows the gate leaf