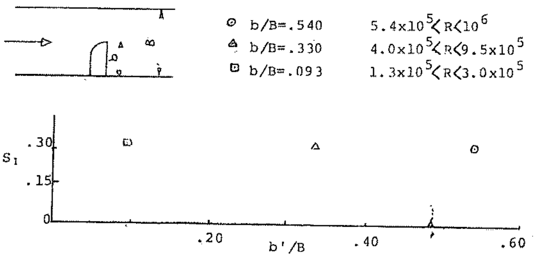

FIG. 7a Variation of Modified Strouhal Number with Blockage (non-cavitating), Boundary Element (normal orientation)

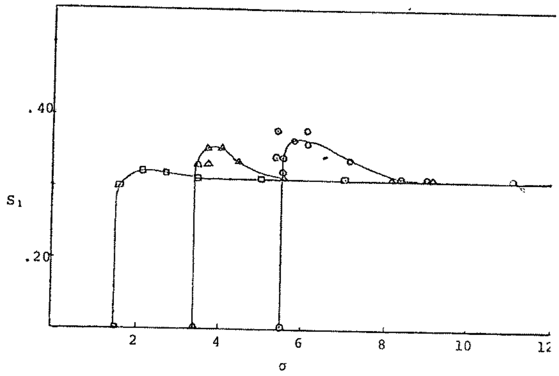

FIG. 7b Variation of Strouhal Number with Cavitation Number, Boundary Element (normal orientation)

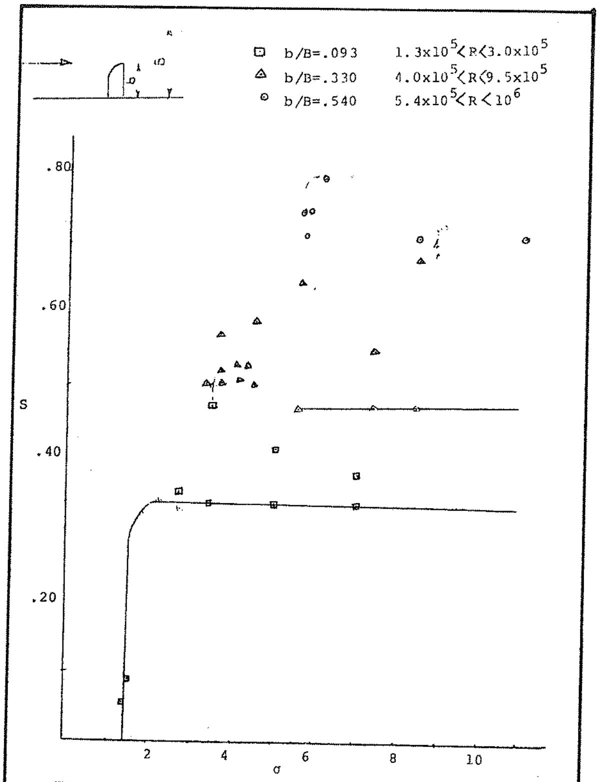

FIG. 6 Variation of Strouhal Number with Cavitation Number, BOUNDARY Element (normal orientation)

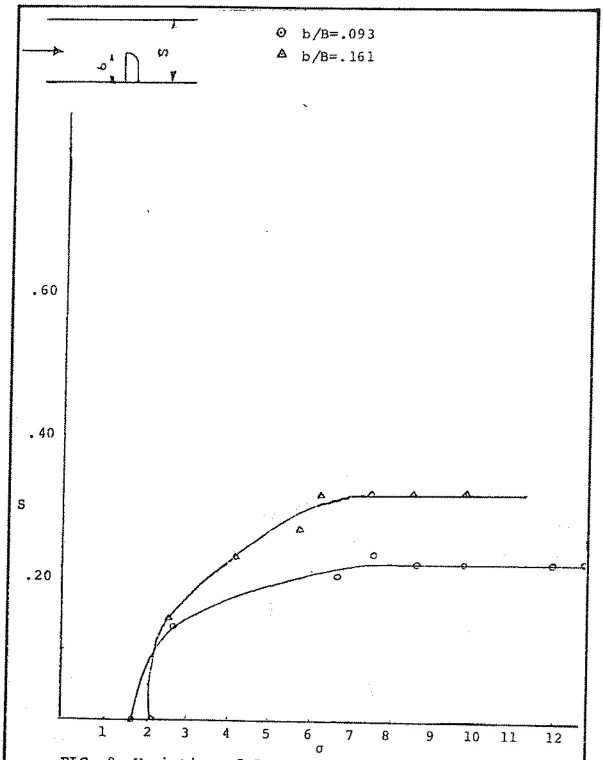

FIG. 8 Variation of Strouhal Number with Cavitation Number, Boundary Element (reversed orientation)

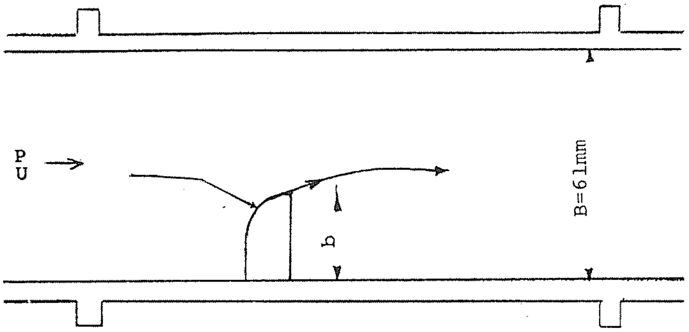

FIG.3 MODIFIED-TEST SECTION

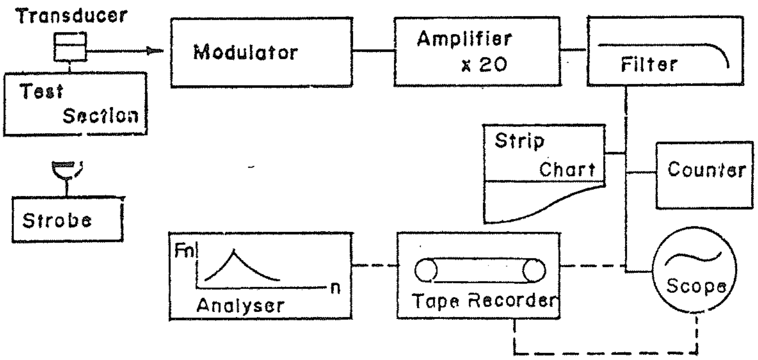

FIG. 4 INSTRUMENTATION

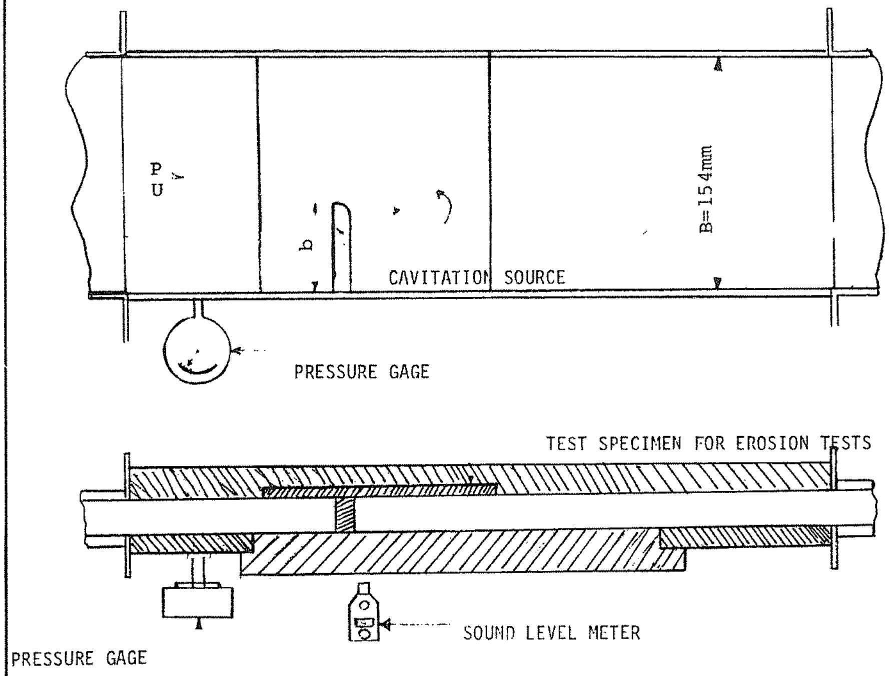

FIGURE 5 - TEST SECTION FOR NOISE AND EROSION TESTS
(modified test section)

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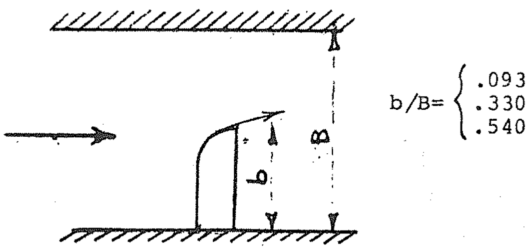
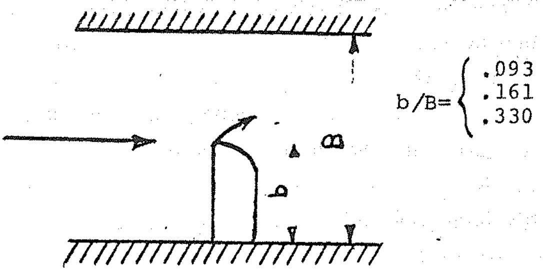


a) NORMAL ORIENTATION



b) REVERSED ORIENTATION

FIGURE 2 - CAVITATING BOUNDARY ELEMENTS

shedding frequency was obtained with the help of a pressure transducer located in the edge of the wake region of the course. The location of the transducer for different sizes of the model was determined by trial and error to register the primary vortex shedding freguency. The associated instrumentation is shown in Fig. 4. The amplified signal was recorded on a strip chart recorder and the recorded signals were often checked with the help of a frequcncy counter. An analyser (B & K) fitted with a level recorder was used for spectral analysis of the recorded data, especially when the frequcncy of vortex shedding was not discernible from direct records of the strip chart. For this purpose, large enough time samples were chosen on the time axis, in order to be able to make a representative statistical average over the entire recorded signal and that was about $\frac{400}{f}$ seconds.

Besides the larger test section (154 mm 6mm), a narrower test section (6mm 61mm) was used to conduct an erosion test which required much larger velocities. The narrow test section was also used for the noise tests.

The noise radiated by the boundary element was measured with the help of a noise meter (B & K). A simple parabolic - shaped device was used to house the transducer (Fig. 5). The sound level meter was located at about 150mm from the face of the test section in the horizontal plane. The sound level meter had a built - in octave filter set with eleven band pass filters in the range of 31, 5 H 7 to 31. 5 KHZ.

Sound pressure levels were obtained for different cavitation numbers at fixed flow velo cities.

Some tests were conducted to determine the erosion characteristics of flow past boundary elements.

For this, soft aluminum test specimens were mounted in the wake region of the boundary elements. Since the number of erosion tests conducted were very few, no detailed analysis of the test results were made. Nevertheless, the soft aluminum plates housed in the wake of the boundary elements were eroded considerably during short term (30 minutes) tests. This indicated the feasibility of using the narrow section for erosion tests.

Conclusions & Suggestions.

2 - 1 Conclusions.

Based on the present study, the following conclusions can be reached.

(1) For constrained flow past the boundary element set in the normal orientation the gap velocity U_1 is the proper velocity scale that yields a modified Strouhal number S_1 which is nearly constant over a large range of cavitation numbdrs.

For all blockages considered in the present study the relationship between S_1 and σ_1 is almost unique.

(2) As the cavitation number is varied over a wide range for constrained cavitating flow past the boundary element set in the reversed orientation, the peak radiated noise occurs in a very narrow band of cavitating numbers.

2 . 2 Suggestions.

Detailed studies should be made to confirm the results of preliminary studies and vortex shedding characteristics of boundary elements. As a part of this study, one should investigate the relationship between the value of «K» and blockage for the two boundary elements considered.

ANALYSIS OF RESULTS

2.1 Boundary Elements (normal orientation)·Since the Reynolds number of the flow was close to the critical Reynolds' number, the vortex shedding frequency and hence the Strouhal numbers S display a wide scatter (Fig 6). Consequently , it is difficult to establish the dependence of S and s_1 on a cavitation number. In spite of this, mean curves were drawn to indicate the dependence of S and S_1 on the cavitation number (Fig 6, 7).

Fig, 7 (a) shows th effect of blockage and the vortex shedding frequency of the boundary elements set in the normal orientation. The cavitation number of the flow was very large (none cavitating). The modified Strouhal number S_1 was based on the gap velocity U_1, (Fig 7) while the Strouhal number S was based on the und isturbed velocity U. The vortex shedding of these elements ceased when choking conditions prevailed. Similar observations have been made for flow past bluff bodies (18). As a further attempt to unify the data, the modified cavitation number 6_1 was adapted to include the relationship between S_1 and 6_1 which appears to provide a nearly unique representation between these two variables for a wide range of blockage.

1 - 2 VORTEX SHEDDING FREQUENCY

Vigander (2) used high speed photography to obtain the vortex shedding frequeney for flow past boundary elements as shown in Fig. 2 (a). He states that «the intensity of pressure fluctuations at the vortex shedding frequeney decreases in the downstream direction. This decrease, represents the decay of the vortices as they are convected downstream».

He also states that covitation in the quasi - steady region reduces the frequency of vortex shedding formation to one - half the frequency of vortex formation in non cavitating flow. Appel (1) has made some studies related to the effects of blockage on vortex shedding. According to him the vortex shedding frequency related to flow past a rigid housed in a conduit is different from that of the flow past a spring mounted gate. The latter gives rise to hydroelastic vibration which is controlled by the elastic characteristics of the gate. For the rigid gate, he observed that eddy behind the gate is stable. For flow past a normal plate subject to constrained flow, shaw (13, 14) states that the ratio of the separation velocity to the uniform approach velocity denoted by the factor «K» increases uniformly with B/d. Note that the variable factor «K» is related to the Jet contraction velocity Uj is equal to the separation velocity Us when the blockage is at least moderate. It may be added that the contraction coefficient is a weak function of blockage for high blockage ratios.

1-3 BLOCKAGE EFFECTS.

1.3.1 Non cavitating sources

In water tunnel tests, side walls of the test section can change the hydrodymic force coefficients and the vortex shedding Frequency of the model set in the test facility. Several investigations have been made to determine the effect of blockage on the drag coefficient (10,11) and Strouhal number (4, 5, 6, 7, 8) of non - cavitating bluff bodies. It has been shown that the separation velocity Us (Fig 3) is the characteristic velocity scale that should be used to normalise the drag coefficient when the blockage effects are severe (5, 9, 10, 11, 12). Further, when the configuration of the body is similar to the one shown in Fig 2 (a) the contraction coefficient Cc is a weak function of blockage. As such, the gap velocity U_1 (Fig 2 b) can be used in place of Us (or Uj) in normalising - the vortex shedding frequency for flow past such elements.

1. 3 . 2 Cavitating Souces

Very recently Popp (22) has analyzed the problem of wall effects in cavitating flows and his conclusions are in very good agreement with he studies of wuetal (15, 16) Bhaskaran (18) has recently conducted an experimental study related to blockage effects on bluff bodies set in a two - dimensional test section.

According to his results the gap velocity U_1 (Fig 3) and the jet contraction velocity Uj are the proper velocity scale to normalise the drag force and the vortex shedding frequency for constrained cavitating flow past bluff bodies. Earlier studies related to the vortex shedding characteristics of flow past cavitating bluff bodies include those of Syamala (19), Young (20) and Hammitt (21). The present project was under taken to achieve the following goals.

1 - Develop a simple test set - up which can be used to determine the characteristics of constrained cavitating flow past simple boundary elements.

2 - Conduct preliminary tests to check the feasibility of conducting comprehensive test programes related to the following aspects of cavitating flow past boundary elements:

(i) Vortex shedding characteristics including blockage effects.

(ii) Cavitation noise characteristics.

(iii) Cavitation errosion characteristics.

3 - Correlate data of preliminary tests related to, (i) and (ii) above, and arrive at tentative conclusions.

Experimental Set_Up

The present investigation was carried out in the two dimensional test section (154 mm 6mm) of a venturi flow apparatus which was developed for the study of flow past roughness elements mounted on the walls of the test section. One side of the test section was made of thick plexi glass to aid both stroboscopic and high speed photographic studies. Polished stainless steel roughness elements formed the basic shapes for the cavatation sources (Fig. 2). The minimum hight of the model was 16mm . The model was mounted in the test section, as shown in Fig. 3. Static pressure taps were housed in the windows of the test section and these were connected, in turn, to the manometers and pressure transducers. The flow was measured with the help of a calibrated venturimeter. The vortex

Constrained Cavitating Flow Past Simple Boundary Elements

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NOMENCLATURE

b	source size (width)
B	width of test section
B/b	blockage (constraint)
Cc	contraction coefficient
f	frequency of vortex shedding
P	pressure in undisturbed approaching flow
Pv	vapor pressure
R	Reynolds number (Ub/v)
S	Strouhal number normalized by U (= fb/U)
S_1	Strouhal number normalized by U_i (= fb/U)
S P L	sound pressure level (dB) = $20\log_{i}(p/pref)$
U	mean velocity of undisturbed approaching flow
U_i	mean gap velocit (Fig. 3)
Uj	contracted jet velocity. (Fig. 3)
Us	velocity along the separation streamline (Fig.3)
W	frequency (cps) in noise spectra
V	Kinematic viscosity
P	densitg of fluid
σ	cavitation number $(P - P_v) / 1/2\, Pu^2$
σ_1	cavitation number $(P - P_v) / 1/2\, PU_1^2$

$$K = U_s / U = \frac{B}{C_c\,(B-b)} \qquad U_j - U_l / C_c$$

$$\sigma_1 = (1 - b/B)^2 \sigma \qquad U_1 = U / (1 - b/B)$$

$$S_1 = (1 - b/B)\, S$$

Abstract:

A development project was undertaken to design a test set up to study the characteristics of noise and vortex shedding frequcncy related to constrained cavitating flow past simple boundary Elements. The boundary element for which the forebody was streamlined is arbitrarily designated as the element set in the normal orientation, the boundary element with the vertical front face is designated as the element set in the reversed orientation.

The present studies indicate that the gap velecity U_1 is the proper velocity scale to normalise the vortex shedding frequenicy for flow past the baundary element set in the normal orientations. the preliminary results also indicate that the noise radiated by cavitating flow past the boundary elements set in the reversed orientation attain a peak value (RMS) in a narrow band of cavitation numbers for all blokage tested.

INTRODUCTION

General Remarks

1 - 1 When the local pressure in flowing liquid is sufficiently lowered either by increasing the ambient velocity or by decreasing the ambient pressure, a fully developed cavity attached to a solid boundary occurs. This characteristic of the flow is generally determined, to a large extent by 6. The ratio of model area to the test section area is denoted as blockage and it determines the influence of the side walls on the characteristics of flow. Some studies have been made in the past, to understand the effect of blockage on the wake produced by flow passing over boundary elements under cavitating conditions (1, 2, 3). The present effort is principally concerned with the development of a set - up to study the effects of blockage on the vortex shedding frequency and noise associated with, cavitating flow past boundary elements set on the wall of two dimensional venturi set - up.