

# The use of self-resonating cavitating water jets for underwater sound generation

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A self-excited cavitating jet assembly is examined for possible use as an underwater noise generator. The principles of the system are based on matching the natural frequency of a submerged jet with that of a resonant chamber through a feedback mechanism. The case of an organ pipe resonant feed tube is thoroughly investigated. In this case, feedback is obtained by shaping the nozzle in order to optimize its interaction with instabilities in the shear layer of the jet. The performance of the noise generator is evaluated and its characteristics analyzed, including the influence of the pressure drop across the nozzle, the cavitation number, and the organ pipe length. It is observed that the efficiency of STRATOJETs (self-resonating cavitating jets) is more than two orders of magnitude higher than that of a conventional cavitating jet. The knowledge developed in this study allows for selection of the amplitude and frequency of the emitted noise by proper dimensioning of the assembly and correct choice of the functioning conditions.

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## LIST OF SYMBOLS

$a_0$	initial cross-section radius of the toroidal cavity	$P_h$	hydraulic power
$a$	cross-section radius of the toroidal cavity	$P_v$	vapor pressure of the liquid
$\bar{a}$	$a/a_0$	$P_s$	sound power
$A_{cav}$	noise amplification due to cavitation	$P_\infty$	imposed pressure field far from the bubble
$c$	sound speed in the liquid	$r$	distance from noise source
$d$	nozzle diameter at jet exit	$R_0$	overall bubble ring radius
$D$	inside diameter of organ-pipe tube	$Re$	Reynolds number, $\rho Vd/\mu$
$D_f$	inside diameter of feed-pipe to the organ tube	$S_d$	Strouhal number, $fd/V$
$e$	nozzle lip thickness	$t$	time
$f$	frequency of oscillations	$\bar{t}$	$t/T$
$k$	polytropic coefficient of noncondensable gas in the bubble	$T$	bubble ring characteristic time, Eq. (24)
$K$	wavenumber	$v'$	velocity fluctuations, rms value
$K_n$	oscillations' mode parameter; defined in Eqs. (4) and (5)	$V$	jet velocity
$L$	organ pipe length	$\mathcal{V}$	bubble volume
$M$	jet Mach number, $V/c$	$\alpha$	jet acoustical pressure coefficient
$n$	mode number	$\gamma$	surface tension coefficient
$p'$	pressure fluctuation, rms value	$\delta P$	driving pressure for bubble implosion
$p_{cav}$	pressure due to cavitating bubble ring collapse	$\Delta P$	pressure drop across the nozzle
$P_{cav}$	amplitude of pressure peaks due to bubble collapse	$\epsilon$	correction coefficient for tube length
$p'_h$	pressure fluctuations measured by the hydrophone	$\Gamma$	circulation, $V\lambda$
$P_a$	ambient pressure	$\lambda$	wavelength of oscillations
$P_g$	noncondensable gas pressure inside the bubble	$\eta$	acoustic efficiency
		$\rho$	liquid density
		$\mu$	fluid viscosity
		$\sigma$	cavitation number, $(P_a - P_v)/\Delta P$
		Superscript (·)	time derivative

## INTRODUCTION

Cavitation is mainly known for its harmful effects, namely, loss of performance, erosion, and noise. The usual procedure to prevent these deleterious effects is to avoid the phenomenon by proper design and by limiting the operating conditions. However, attempts to induce and harness cavitation for useful purposes have been increasingly successful. Ultrasonic cavitation methods take advantage of the erosive

power of cavitation for cleaning, emulsification, and mixing.<sup>1</sup> In high pressure jets, cavitation is purposely induced in order to increase their drilling, cutting, and cleaning capabilities.<sup>2</sup> The noise associated with cavitation is being studied as a means of sensing when it becomes destructive and, hence alleviating its damaging effects.<sup>3</sup> In this paper, we will present a more direct utilization of cavitation noise: underwater sound generation.