1. Introduction

This theory was inspired by experiments of J. H. Olsen and B. A. Thomas, who developed a lightweight continuous pressure intensifier for a water jet. The intensifier raises the stagnation pressure of the water up to 20,000 psi, well above the compressive strength of concrete and many rocks. The water jet should serve as a quiet and wear-free cutting tool, a replacement for the jack-hammer.

A developed technology of hydraulic rock cutting would play a major role in the emerging era of rapid transportation. Clearing away existing concrete roads and structures is enormously expensive, and the cost of tunneling depends mainly on the speed with which rock can be penetrated. Despite the economic motivation, little is known about the fundamental mechanics of hydraulic rock cutting, and in fact the action of its traditional competitor, the jack-hammer, is a matter of current research [1].

The English literature on hydraulic rock penetration begins with Farmer and Attewell [2], who released a transient water jet against fixed targets. As a qualitative model of penetration, they imagined the jet impacting as a train of solid projectiles and deforming the rock plastically by momentum transfer. They derived from their experiments an empirical formula for the depth of penetration, but the formula was not consistent with the momentum-transfer argument.

Farmer and Attewell were followed by Leach and Walker [3], who were mainly concerned with the effect of nozzle shape on the coherence of the jet. They performed limited experiments on rock penetration by ejecting 10 cm^3 of water under pressures ranging from 1000 to 6000 atm. They discovered that no penetration occurs if the total pressure P_o of the jet stream lies below a critical value P_c, which depends on the type of rock. The depth of penetration appeared to be proportional to $(P_o - P_c)$ above the critical pressure, the constant of proportionality depending again on the type of rock. It is worth noting that a high constant of proportionality did not imply a low value of P_c, which means that initial fracture and final depth of penetration are controlled by different mechanisms. Brook and Summers [4] followed with an experimental study of penetration into static targets as a function of standoff distance, driving pressure P_o, and duration of the jet stream. The penetration depth was proportional to P_o, rising rapidly in the first few milliseconds of jet impingement, then much more gradually with further elapse of time. The critical pressure P_c was too low for observation,