N88-22414

SYSTEMS FOR ULTRASONIC SCANNING, ANALYSIS, AND IMAGERY

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ABSTRACT

A variety of ultrasonic scanning and imagery techniques are used to investigate various aspects of materials and microstructures. Two ultrasonic scanning systems are in use by the Lewis Research Center's Structural Integrity Branch: an immersion scanner and a contact scanning system. The basic principles of scanning are reviewed, examples of images are presented, and structural features suggested by these images are discussed. Both of these systems are custom designed; their unique capabilities, advantages, and disadvantages are highlighted.

*Sverdrup Technology, Inc., Lewis Research Center Group. Work performed on-site at the Lewis Research Center under contract NAS3-2410S.

†Cleveland State University. Work funded under NASA Grant NCC3-24.

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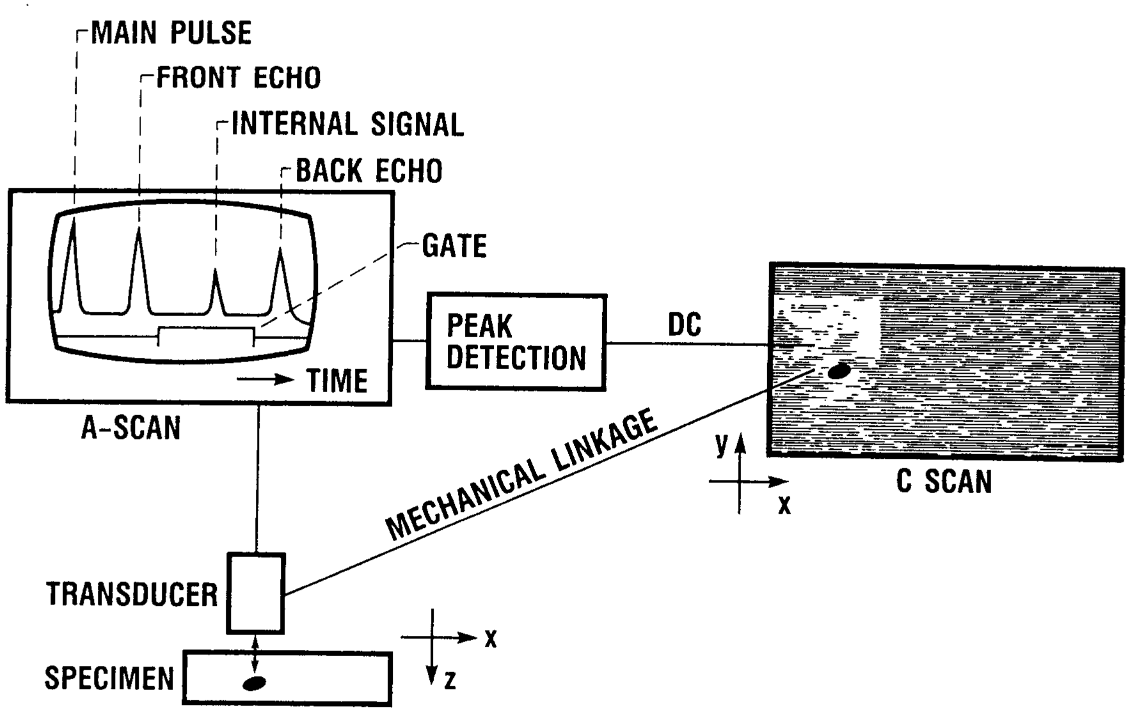
C-SCAN PRINCIPLES

In general, ultrasonic scans are based on the following procedures: A specimen with flat, parallel surfaces is immersed in water. A transducer is used to send a very short pulse which echoes off the front and back as well as flaws within the specimen. The transducer receives the echoes and they appear on an oscilloscope (A-scan trace) where echoes returning from points farther from the transducer are farther to the right on the time trace. Signals of interest are highlighted by an adjustable time gate, and the peak amplitude of the gated signal is converted to a dc signal. This signal is used to create an x-y image (C-scan), where traditionally the signal controls the intensity of an electrostatic pen moved as the scan progresses by a linkage attached to the transducer manipulator.



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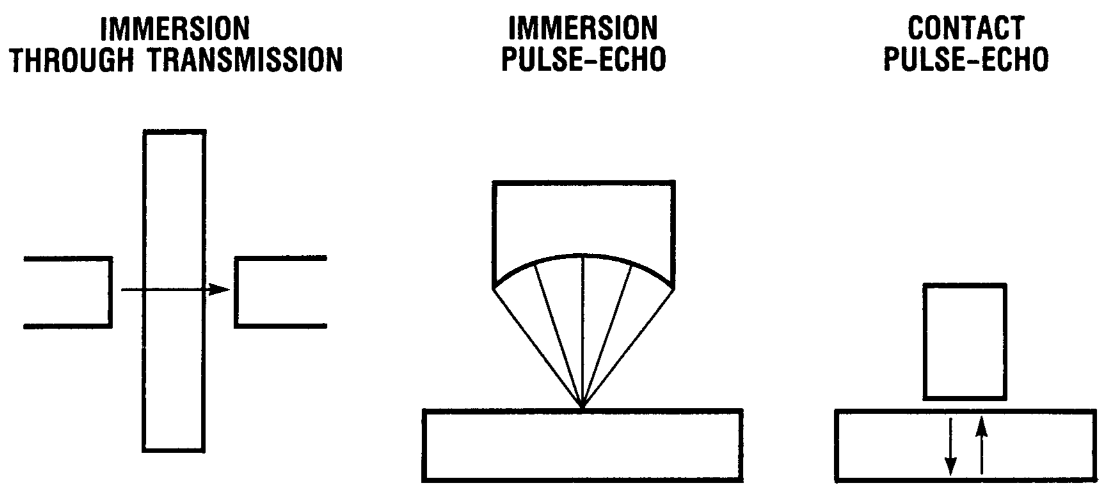
TYPES OF ULTRASONIC SCANS

In through-transmission scans, two transducers are used - a pulser and a receiver - and the signal transmitted through a relatively thin sample is examined in a plane parallel to the sample. In pulse-echo scans, the echoes are of interest and could be those from the specimen front or back surface or from inside. The transducer could be focused, where the sound waves converge to a point. In contact scans, a thin layer of oil or glycerin is used as couplant between the transducer and the sample in place of water.



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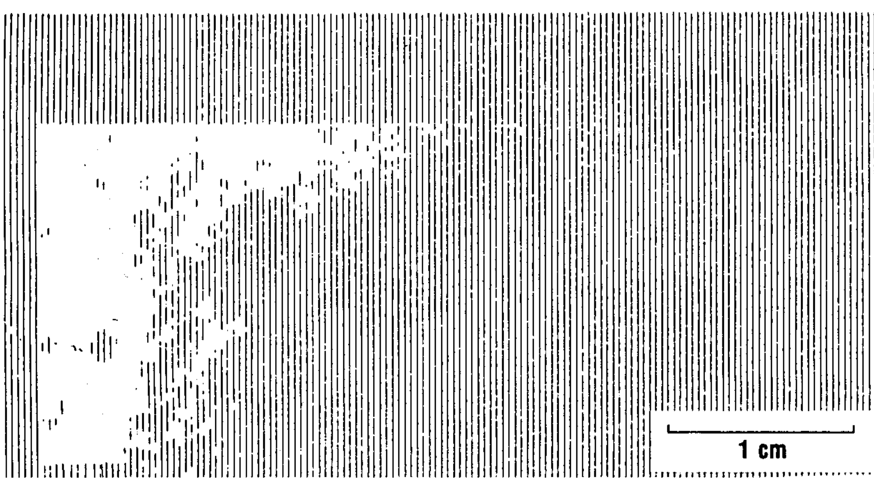
THROUGH-TRANSMISSION C-SCAN OF COMPOSITE PANEL

Displayed here is a conventional through-transmission C-scan image of a carbon composite panel produced by the electrostatic pen method. Higher amplitude transmitted signals are indicated by dark traces. The lower amplitude areas suggest poor bonding, but good contrast and quantitative results are difficult with this method.



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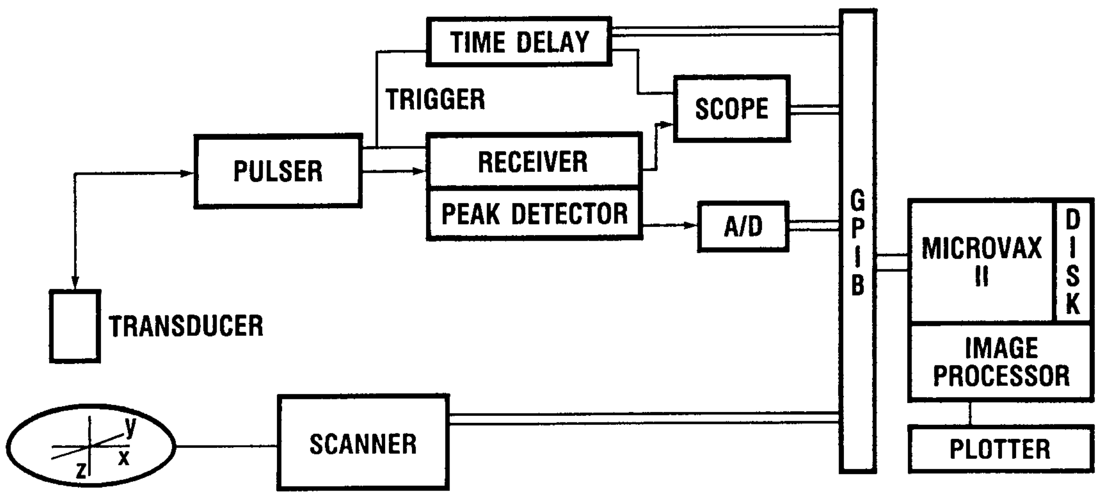
MODIFIED IMMERSION ULTRASONIC SCANNING SYSTEM

An ultrasonic C-scan system was modified by omitting the use of the electrostatic pen plotter and sending the peak-detected dc signal to an analog-to-digital converter (A/D). This signal is sent to a MICROVAX II computer which controls the scan and acquires the digitized data through the IEEE-488 (general-purpose interface bus). A Grinnell image processor then displays a gray scale or color image of the scan.



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DIGITAL SURFACE SCAN IMAGE

This is an image obtained from a scan using a 75-MHz transducer focused at the surface. The scanner resolution is 96 μm (the limit of this system is 24 μm), and such an image can be zoomed to virtually any size. Note that not only are the coin's stamped features vividly brought out, but also small flaws such as nicks are imaged.

DIRECT SURFACE REFLECTION USING FOCUSED TRANSDUCER

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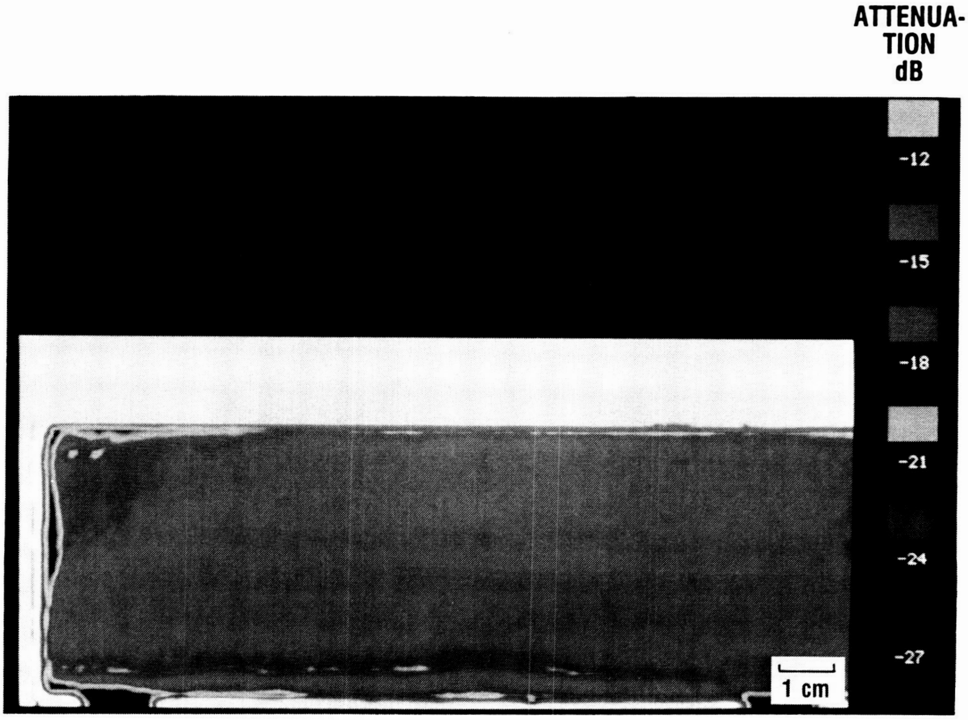
DIGITAL THROUGH-TRANSMISSION IMAGE OF METAL MATRIX PANEL

Shown here is a through-transmission image of an iron-aluminum matrix, silicon carbide reinforced panel, produced using the modified C-scan system and 20-MHz transducers. The color scale indicates decibels of attenuation compared with a signal traveling through water unobstructed. This method of scanning creates a more quantitative and better contrasting result. The difference in attenuation can indicate the quality of bonding between matrix and reinforcement since a poor bond would cause ultrasonic energy to reflect rather than transmit through.



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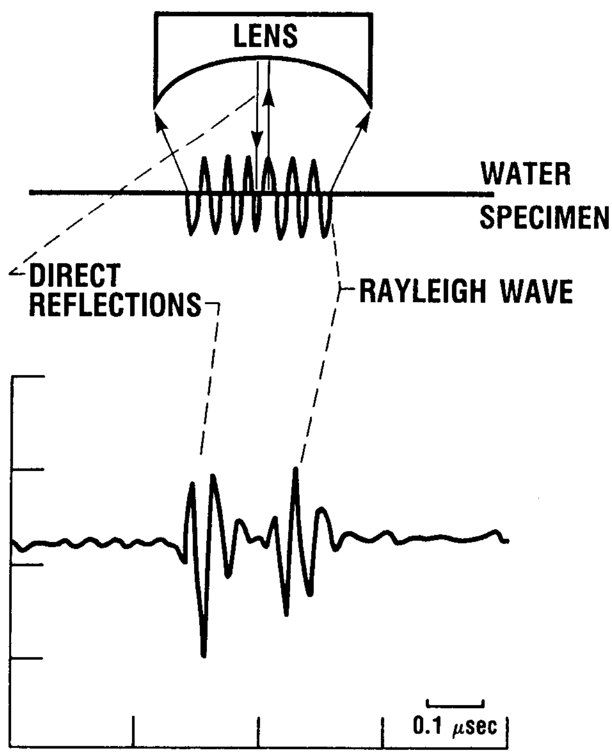
RAYLEIGH WAVE SIGNAL

Another type of ultrasonic scan involves the recording of the surface (Rayleigh) wave signal by moving a focused transducer closer to the surface than the focal length. A wave traveling from the outer portions of the lens at some critical angle relative to the specimen surface will produce a surface wave in the sample and return again to the transducer lens. This signal appears slightly later than the main surface echo and can thus be recognized and gated (Gilmore et al., 1986; and Quate, 1980).



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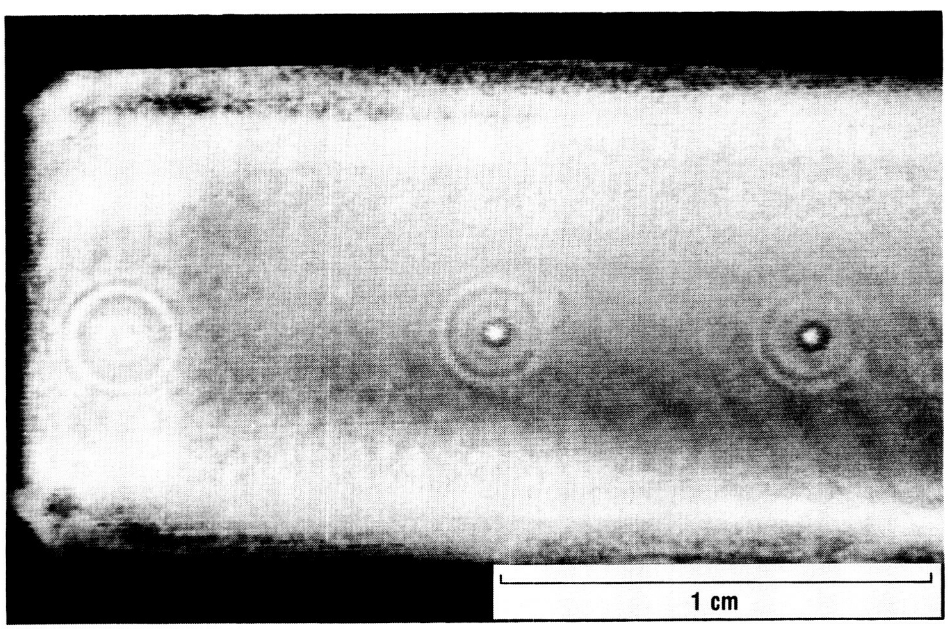
RAYLEIGH WAVE SCAN IMAGE

Images produced from the acquisition of the Rayleigh wave peak indicate features on the specimen surface as well as those near the surface (within a wavelength). Shown here is a scan using a 50-MHz transducer of a silicon carbide bar with seeded subsurface 50-μm voids. Such features cause disturbances in the Rayleigh signal, producing diffraction-like ring patterns.

BAR WITH SEEDED VOIDS



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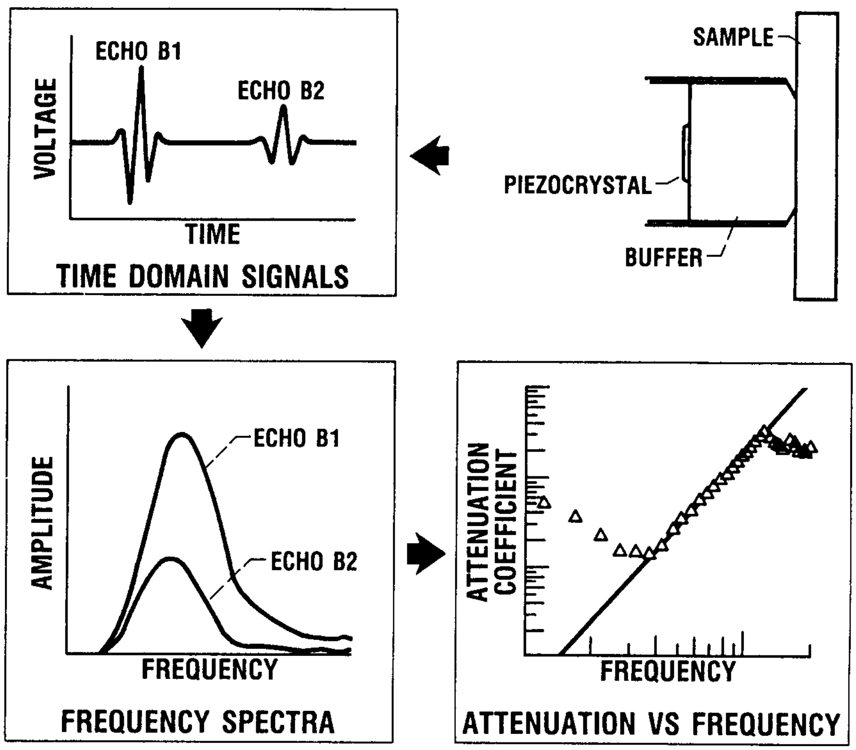
CONTACT SCANNING AND ANALYTICAL ULTRASONICS

Analytical ultrasonics refers to any method where waveforms (as opposed to simply a peak) are processed to reveal how microstructure alters the wave. Here, two successive back wall echoes are processed to find attenuation versus frequency. Sound velocity can also be calculated by finding the travel time between pulses. These methods generally are used for finding bulk characteristics rather than individual defects (Vary, 1986).



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IMAGING SUBTLE FEATURES WITH ANALYTICAL ULTRASONICS

Shown here are contact scans of a monolithic silicon carbide disk. Variations in the sound velocity indicate differences in density over the area of the disk that x rays cannot image as well. In addition, differences in pore size are indicated by variations in ultrasonic attenuation (Generazio et al., 1988).

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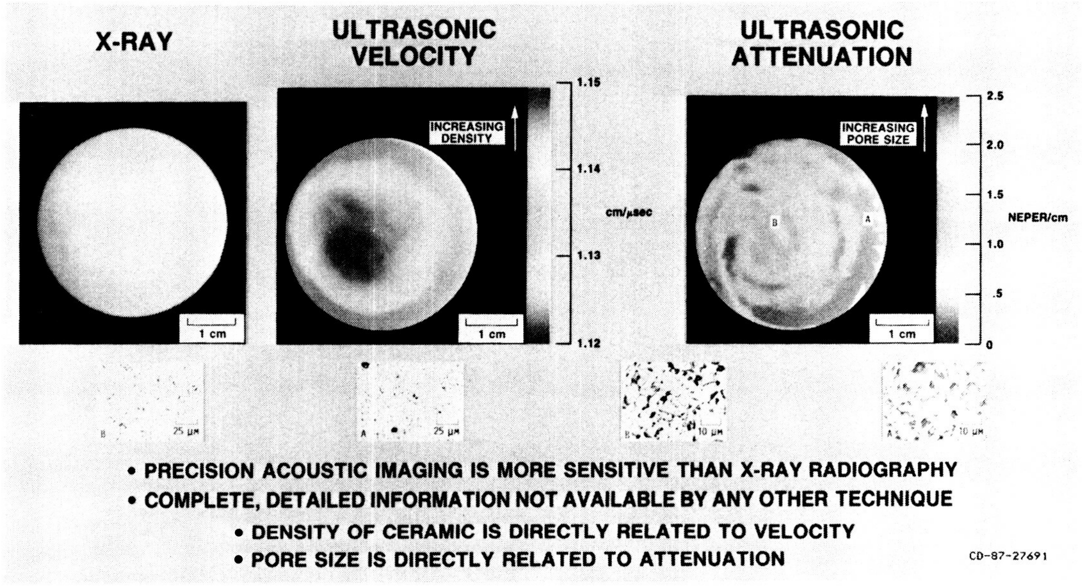

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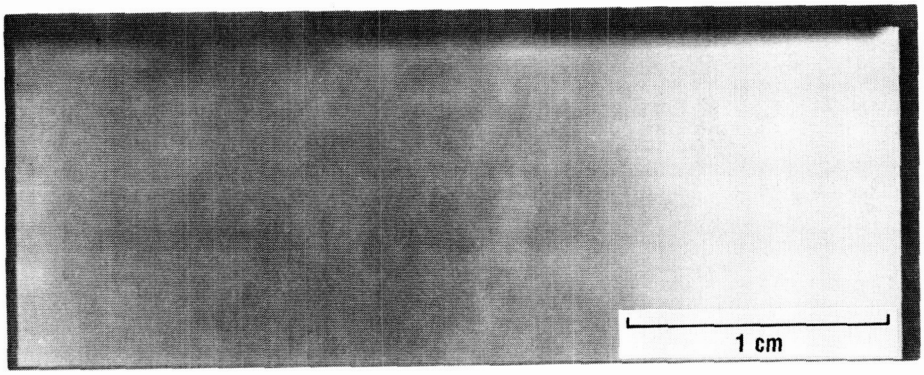
ULTRASONIC VELOCITY OF ALUMINA SAMPLE

This is an x-y image representing the velocity of sound through the bulk of an alumina specimen. The scan resolution is 0.5 mm; the sound velocity ranges from 0.984 (light areas) to 0.994 cm/μsec (dark areas). The regions of lower velocity are believed to be slightly more porous.



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