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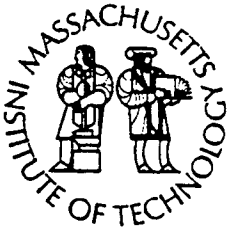

DOCTORAL DISSERTATION

Fluid Flow and Sound Generation at Hydrothermal Vent Fields

by

Sarah A. Little

April 1988

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Woods Hole, Massachusetts 02543

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Cambridge, Massachusetts 02139

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Doctoral Dissertation

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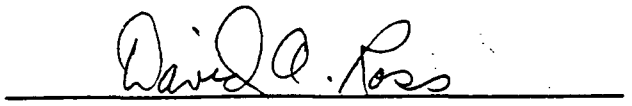

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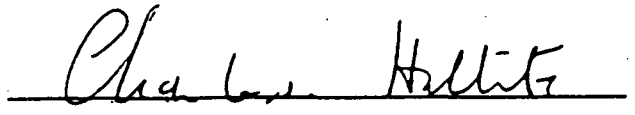

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FLUID FLOW AND SOUND GENERATION AT HYDROTHERMAL VENT FIELDS

by

Sarah Alden Little

B.S. (1981) Stanford University

Submitted in Partial Fulfillment
of the Requirements for the Degree of

Doctor of Philosophy
at the
Massachusetts Institute of Technology
and the
Woods Hole Oceanographic Institution

April 8, 1988

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FLUID FLOW AND SOUND GENERATION AT HYDROTHERMAL VENT FIELDS

by

SARAH ALDEN LITTLE

Submitted to the Department of Earth, Atmosphere and Planetary Sciences
on April 8, 1988
in partial fulfillment of the requirements for the
Degree of Doctor of Philosophy in
Marine Geophysics

ABSTRACT

Several experiments are presented in this thesis which examine methods to measure and monitor fluid flow from hydrothermal vent fields.

Simultaneous velocity, temperature, and conductivity data were collected in the convective flow emanating from a hydrothermal vent field located at $10^{\circ}56'N$, $103^{\circ}41'W$ on the East Pacific rise. The horizontal profiles obtained indicate that the flow field approaches an ideal plume in the temperature and velocity distribution. Such parameters as total heat flow and maximum plume height can be estimated using either the velocity or the temperature information. The results of these independent calculations are in close agreement, yielding a total heat flow from this vent site of 3.7 ± 0.8 MW and a maximum height of 150 ± 10 m. The nonlinear effects of large temperature variations on heat capacity and volume changes slightly alter the calculations applied to obtain these values.

In Guaymas Basin, a twelve day time series of temperature data was collected from a point three centimeters above a diffuse hydrothermal flow area. Using concurrent tidal gauge data from the town of Guaymas it is shown that the effects of tidal currents can be strong enough to dominate the time variability of a temperature signal at a fixed point in hydrothermal flow and are a plausible explanation for the variations seen in the Guaymas Basin temperature data.

Theoretical examination of hot, turbulent, buoyant jets exiting from hydrothermal chimneys revealed acoustic source mechanisms capable of producing sound at levels higher than ambient ocean noise. Pressure levels and frequency generated by hydrothermal jets are dependent on chimney dimensions, fluid velocity and temperature and therefore can be used to monitor changes in these parameters over time.

A laboratory study of low Mach number jet noise and amplification by flow inhomogeneities confirmed theoretical predictions for homogeneous jet noise power and frequency. The increase in power due to convected flow inhomogeneities, however, was lower in the near field than expected.

Indirect evidence of hydrothermal sound fields (Reidesel et al., 1982; Bibee and Jacobson, 1986) showing anomalous high power and low

frequency noise associated with vents is due to processes other than jet noise.

On Axial Seamount, Juan de Fuca Ridge, high quality acoustic noise measurements were obtained by two hydrophones located 3 m and 40 m from an active hydrothermal vent, in an effort to determine the feasibility of monitoring hydrothermal vent activity through flow noise generation. Most of the noise field could be attributed to ambient ocean noise sources of microseisms, distant shipping and weather, punctuated by local ships and biological sources. Water/rock interface waves of local origin, were detected which showed high pressure amplitudes near the seafloor and, decaying with vertical distance, produced low pressures at 40 m above the bottom.

Detection of vent signals was hampered by unexpected spatial non-stationarity due to shadowing effects of the caldera wall. No continuous vent signals were deemed significant based on a criterion of 90% probability of detection and 5% probability of false alarm. However, a small signal near 40 Hz, with a power level of 1×10^{-4} Pa^2/Hz was noticed on two records taken near the Inferno black smoker. The frequency of this signal is consistent with predictions and the power level suggests the occurrence of jet noise amplification due to convected density inhomogeneities.

Ambient noise from the TAG (Trans-Atlantic Geotraverse) hydrothermal area on the Mid-Atlantic Ridge near $26^{\circ}N$, in the frequency band 1-30 Hz at a range of 0.75-14 km from the site of an extremely active high temperature hydrothermal vent field (Rona, 1986) was examined. The ambient noise field exhibits great temporal and spatial variations attributed in part to typical ocean noise sources such as distant shipping and microseisms. Power spectral levels as measured at each of six ocean bottom hydrophones (OBH) were used to estimate the location of point sources of sound in the area, if any.

The hydrothermal vent did not produce enough sound to be located as a point source using data from the OBH array. The only consistently identifiable point source found with the data set was generating sound in a 0.8-3.5 Hz bandwidth and located outside the median valley. It appears to be harmonic tremor associated with the tip of a ridge on the western side of the spreading axis and may be volcanic in origin.