



Two-Phase Mass Flow Measurement Using Noise Analysis

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May 17, 1999 – May 20, 1999

Geothermal Program Review XVII

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Organization	Idaho National Engineering and Environmental Laboratory
Project Title	Two-phase Mass Flow Measurement Using Noise Analysis
Principle Investigator	Robert P. Evans, Joe G. Keller (INEEL); and Alan G. Stephens, and Jonathan Blotter (ISU)
Presenter	Robert P. Evans
FY98-99 Funding	FY98: \$110K; FY99: \$145K

Project Purpose and FYs 1998 and 99 Objectives: The purpose of this work is to develop a low cost, non-intrusive, mass flow measurement sensor for two-phase flow conditions in geothermal applications. The emphasis of the work to date has been on a device that will monitor two-phase flow in the above-ground piping systems. The flashing brines have the potential for excessive scaling and corrosion of exposed surfaces, which can reduce the effectiveness of any measurement device. A major objective in the work has been the development of an instrument that is less susceptible to the scaling and corrosion effects. The focus of the project efforts has been on transducer noise analysis, a technology initiated at the INEEL. A transducer sensing a process condition will have, in addition to its usual signal, various noise components superimposed upon the primary signal that can be related to flow. Investigators have proposed that this technique be applied to steam and liquid water flow mixtures where the signal from an accelerometer mounted on an external pipe surface is evaluated to determine flow rate..

The objectives of this project in FY1998-1999 are:

- Complete the fabrication and assembly of a test loop that will produce the desired two-phase flow conditions for the planned investigations.
- Conduct preliminary proof-of-concept test to determine whether the proposed transducer noise analysis technique can be applied to the signal of an accelerometer on a pipe surface to determine flow rate.
- With the successful completion of the proof-of-concept test, expand bench scale testing to identify those parameters relevant to making a successful measurement.
- Evaluate test data and determine whether results warrant conducting initial field test of concept.
- Identify location for initial field test of concept.
- Conduct the initial field test with a two-phase flow system to identify potential problems in an actual operating environment.
- Determine whether identified problems are best resolved with additional bench scale testing or expanded field investigations.

FYs 1998 and 99 Performance and FY 2000 Plans: In FY 1998, the construction of a test loop providing two-phase steam and water flows was completed at an Idaho State University facility. This test loop was subsequently used to conduct the preliminary proof-of-concept test. This test showed that the noise on the accelerometer signal increased with the two-phase flow rate as postulated by investigators. The decision was then made to expand the investigation with the test loop to better identify the parameters that define the relationship between the noise signal and the flow rate of the two-phase mixtures. Prior to conducting this expanded test, additional heater capacity was added to the test loop to allow higher flow rates and vapor fractions to be tested. The expanded bench-scale testing was initiated in FY 1998 and completed in early FY 1999. The data collected was evaluated and summarized in an informal report in FY 1999.

The report on the results of the bench scale testing has been distributed for comment to geothermal operators having wells producing two-phase flow. With sufficient industry interest, an initial field test of

the technology will be conducted in the summer of FY 1999. Results of that field test will determine whether the project will pursue additional field testing in FY 2000, or if additional bench-scale testing will be required to resolve those problems identified in the initial testing.

FYs 1998 and 99 Results: The test loop assembled at the Idaho State University facility to provide the steam-water mixtures is shown schematically in Figure 1. This is a closed loop where water is pumped under pressure through an electric heater, flashed across a throttling valve and passed through a 40-foot test section. The steam fraction is then condensed, before the water is recirculated through the loop. The loop was instrumented with the necessary temperature, pressure, and flow (liquid) sensors to adequately monitor the process and determine the two-phase operating conditions. Process data was recorded on a personal computer data acquisition system. The test section consisted of a 40-foot straight test section of 1-1/2 inch, Schedule 160 pipe, on which the accelerometer was mounted. The test loop is capable of producing flow rates to approximately 40 kg/min and steam fractions (by mass) of ~10%. These steam fractions are felt to be representative of those that will be obtained at the surface of a well where flashing occurs within the well bore. Testing with this loop has been conducted in the slug and annular flow regimes as depicted on a Mandhane Chart.

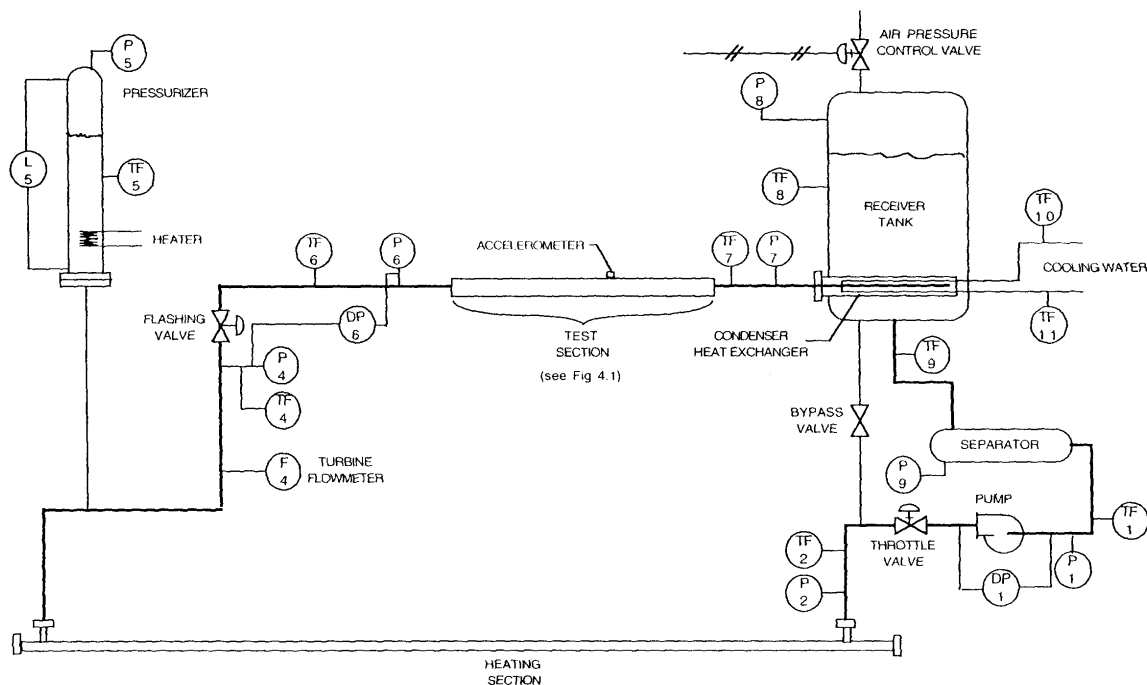


Figure 1. Process flow loop

With the observation that the accelerometer signal noise increased with flow in the proof-of-concept test, the testing was expanded to identify those parameters important to this measurement. For these scoping tests, the effect of two parameters felt to be important to the measurement were evaluated, mass flow rate and steam fraction (or quality). Two separate test sequences were conducted, each where one of these parameters was held constant and the other varied.

The accelerometer data were analyzed by first transforming the data into the frequency domain and performing a power spectral density (PSD) analysis. The 60-Hz component with its associated harmonics

was notch filtered to eliminate noise components associated with electrical components. The notch extended about 5 Hertz above and below the filtered frequency. After transforming back into the time domain, the standard deviation (SD) was calculated for the resulting time-series data. For this investigation the magnitude of the accelerator noise is represented by ratio of the standard of the accelerometer signal to the mean value for a time series of data.

Comparisons of the accelerometer noise with the mass flow rate, show a definite relationship exists between them (Figure 2). A least squares regression produced a standard error of 3 kg/min, which is about 8% of range. This is considered quite good for a scoping test. Because it is difficult to actually hold either the mass flow or the quality constant, it is difficult to remove all of the effects of either mass flow or quality when evaluating the effect of the other on the accelerometer noise. From the data analysis performed, it would appear that mass flow has the greater effect on accelerometer noise. It should also be noted that the range of quality conditions was quite small (up to ~10%). The analysis of the relations between the accelerometer standard deviation and the fluid quality was much less clear. At low quality, there appeared to be a correlation, but as the quality increased, the relationship appeared to go away. Testing was also conducted with liquid water, both hot and cold. Data from this single phase testing, indicated little effect of flow rate on the accelerometer signal noise, leading credence to the conclusion that the noise on the signal was related to the two-phase flow condition.

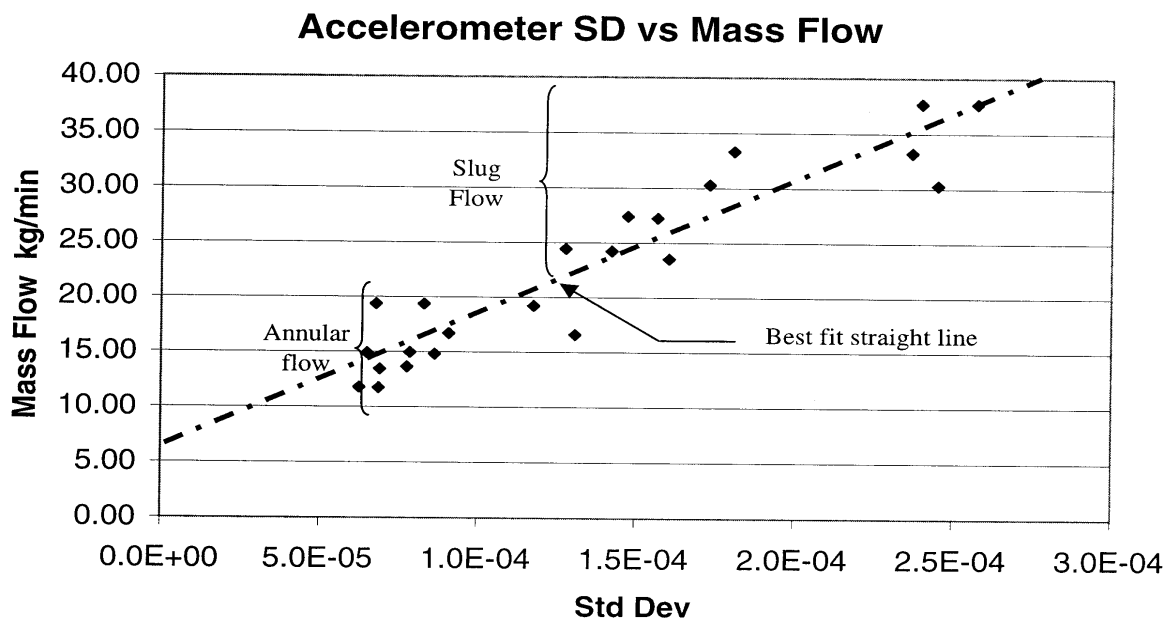


Figure 2. Accelerometer standard deviation versus mass flow for varying mass flow conditions

One of the important issues arose during the expanded scoping testing and the subsequent the data evaluation, is whether the noise observed is “flow-noise” or “flow-induced” noise. If it is noise related directly to the flow conditions, then this technique might be more generically applied to a number of different applications. If the noise on the accelerometer is related to noise from the piping and components that induced by the two-phase flow, then a more sophisticated analysis process may be required or some insitu calibration necessary before technique can be used in an actual application. Investigators currently believe that the observed noise on the signal is related directly to flow, though the

issue has yet to be satisfactorily resolved. Resolution may be come during the initial field testing. If not, it may be necessary to expand the bench-scale testing. This may require testing with an air-water loop to provide better control of the void fractions (quality) and to increase the range vapor fractions tested. Although this will introduce a new set of issues regarding the correlation between results with the two different mixtures, it may be the only way to adequately resolve whether “flow-noise” or “flow-induced” noise is be observed.

Technology Integration:

In the testing to date, the project team has used the expertise of numerous individuals from the Idaho National Engineering and Environmental Laboratory, Idaho State University – College of Engineering, and private consultants with expertise in measuring two-phase flow. It is anticipated that during FY 1999, a geothermal field operator will provide investigators with access to facilities where the preliminary field testing of this concept can be conducted.

During FY1999, a paper, “Two-phase Mass Flow Measurement Using Noise Analysis,” was presented at the 45th International Instrumentation Symposium in Albuquerque, New Mexico. In addition, an Invention Disclosure (LIT-PI-523) and a United States Patent Application (Case Number S-92,166) have been filed.

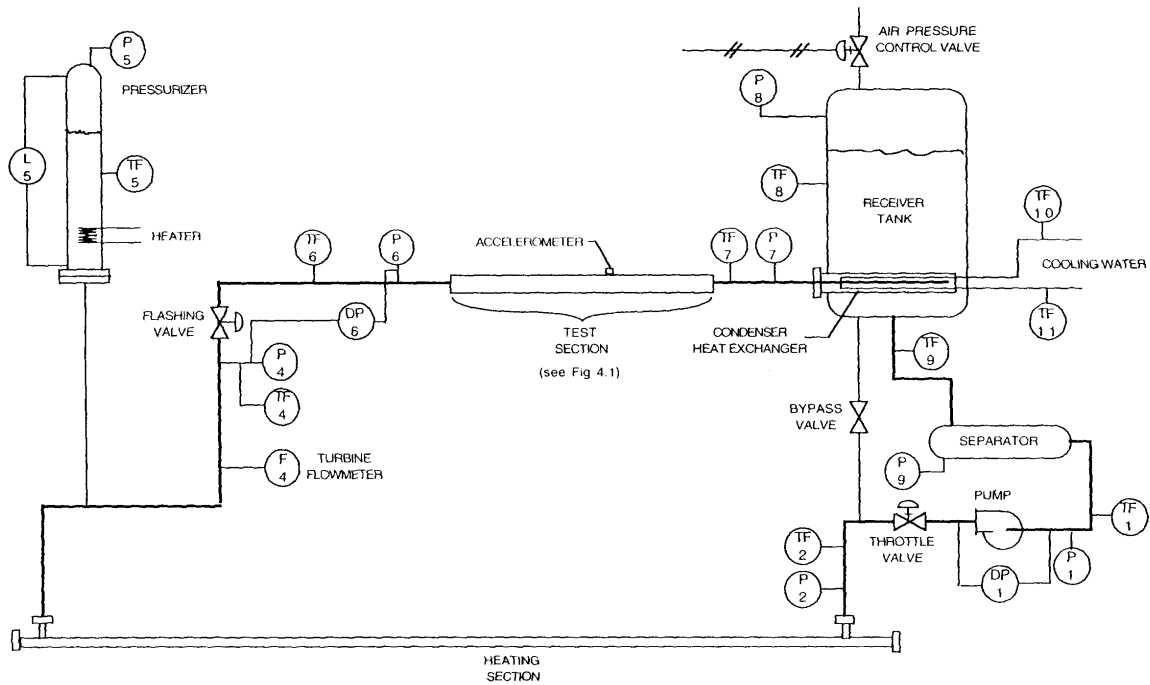


Figure 1. Process flow loop

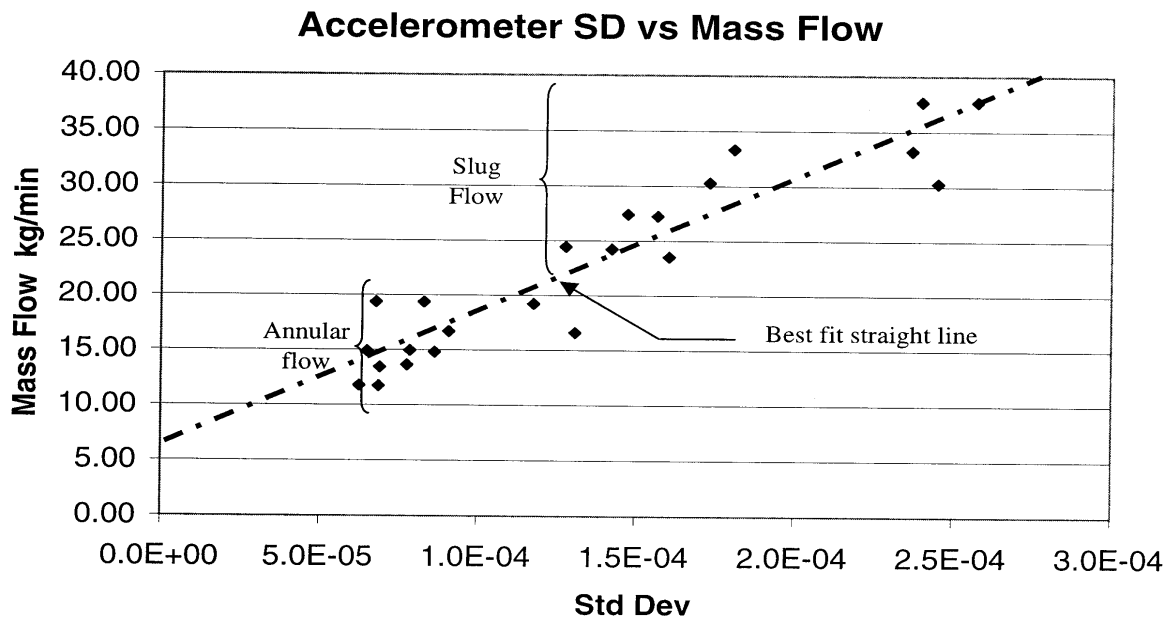


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