ACOUSTIC EMISSION TESTING OF CRYOGENIC VESSELS
"PROBLEMS AND SOLUTIONS"

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INTRODUCTION

The cracking of ice and self generated signals from the transducer due to thermal gradients are sources of extraneous noise signals when conducting AE tests of cryogenic storage tanks. The AE signals due to crack growth in the plate, and cracking of the ice which forms on the surface of the plate have similar high frequency components. Signals generated by the transducer due to thermal gradients also have high frequency characteristics. Therefore traditional AE systems operating at frequencies above 100 kHz and that rely on signal parameters such as rise time, energy, pulse width and spatial filtering have difficulty in determining the difference between these extraneous noise signals and crack growth in the plate. The key to separation and elimination of these extraneous noise signals in real time is first to determine if the AE signal received has plate wave characteristics containing both high and low frequency components. Both crack growth in the plate and cracking of the ice on the plate have these plate wave characteristics, while the extraneous noise signals due to thermal effects are lacking in low frequency components and therefore do not have plate wave characteristics. The AESMART 2000 instrument used for these experiments measures both the high and low frequency amplitudes and the difference in velocity of the high and low frequency components of the AE signal. It is shown by an experiment conducted in this report that these amplitudes and time differences can be used to filter out in real time the extraneous noise sources due to thermal effects and cracking of ice on the surface of the plate.

EXPERIMENTAL PROCEDURE

Figure 1 shows a schematic of the experimental setup used. A small reservoir for holding water was made from modeling clay and placed at the center of the bar used in the experiment. Dry ice was placed on the bar near the reservoir which caused the ice to freeze. A hydraulic jack was then used to place the bar in 3 point bending to crack the ice. An SE9125-MI transducer was coupled to the bar with petroleum jelly at a distance of approximately 300mm from the reservoir. Figure 2 shows the actual experiment.

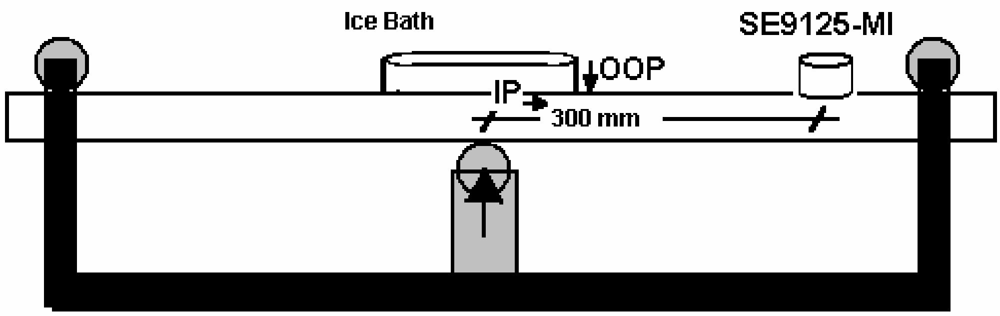

Figure 1

Pretest experiments from pencil leads broken at the reservoir location yielded LF-HF delta Ts in the range from 20 to 50 microseconds. These OOP lead breaks produced an HF/LF modal ratio between 0.9 and 1.5. IP lead breaks made at a shallow depth on the bar at the same location produced modal ratios of greater than 3. Also before testing it was observed that high frequency AE signals with no low frequency component were being recorded. These signals were observed throughout the experiment. The transducer was close enough to the dry ice to experience cooling. These signals were produced due to thermal effects within the sensor.

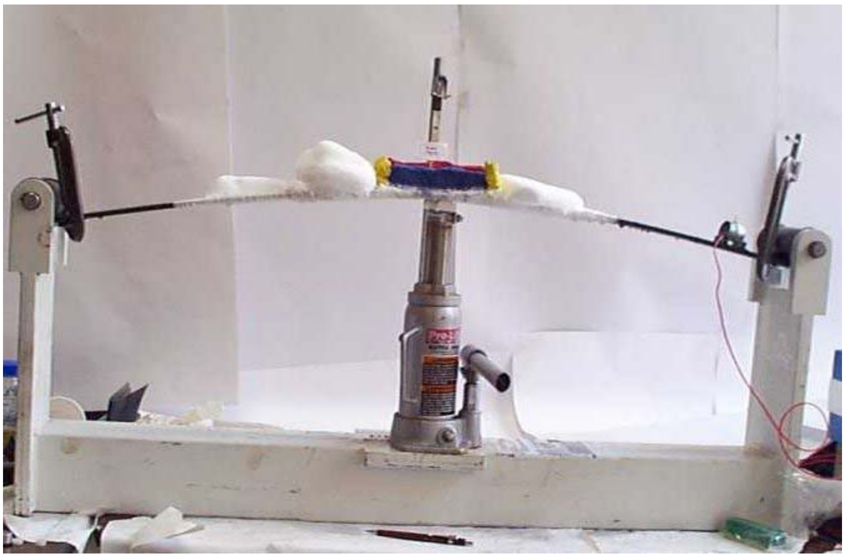

Figure 2. Photo of the bar at high deflection

After the ice was frozen in the reservoir the hydraulic jack was used to deform the bar to cause the ice in the reservoir to crack. After significant cracking in the ice, the bar was unloaded. After testing, the complete set of AE data (no software filters so that all of the raw data was included in the data set) was transferred to an excel spreadsheet for further analysis.

EXPERIMENTAL RESULTS

Figure 3 shows a photograph of the ice after several cracks were produced. The AE signals observed due to the cracking of the ice yielded LF-HF values that correlated well with the LF-HF values obtained from the OOP pencil lead breaks made in the reservoir prior to running the ice cracking test. It was observed that the HF/LF Modal Ratio of the signals rarely exceeded a value of 2. Along with these signals associated with the cracking ice, high frequency signals from thermal gradients in the transducer were also received. These signals yielded HF/LF Modal ratios of infinity and very large values of LF-HF delta T.

Figure 3. Photo of the ice at high deflection with cracks

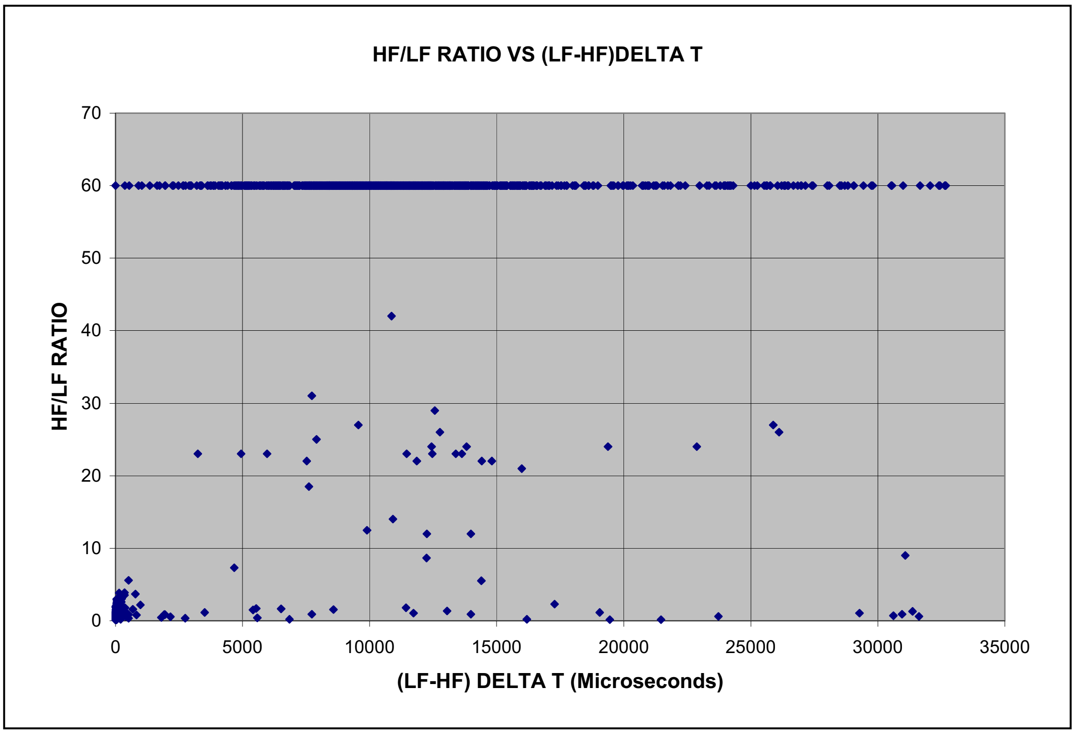

Figure 4. Raw AE data from test with no software filtering.

Figure 4 shows a plot of Modal Ratio vs. LF-HF delta from the test with no filtering. Note that there are a lot of data points due to the thermal effects on the transducer showing a Modal Ratio of 60 which is the software default for ratios of infinity. Infinity ratios are produced when there is no low frequency signal exceeding the set threshold. Since signals generated within sensors produce signals with no LF voltage, the LF-HF delta Ts for these signals are erroneously high. The valid data associated with signals from the cracking of ice is the tight group of data near the ordinates of the graph in figure 4.

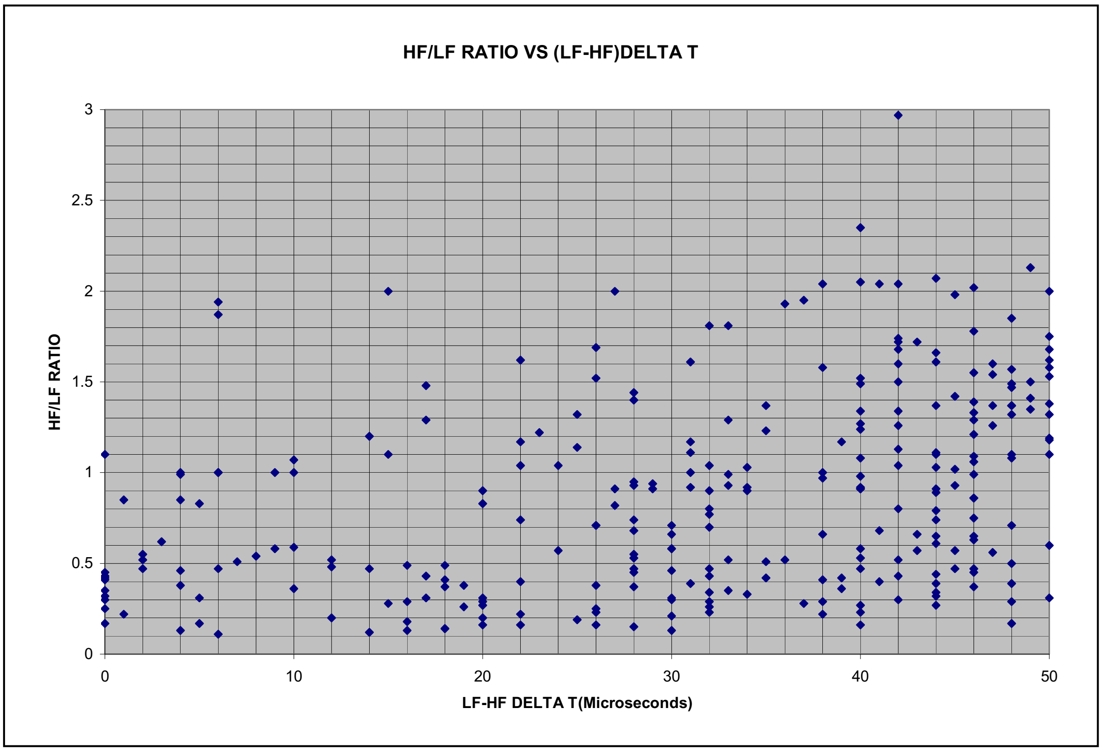

Figure 5. Data in figure 4 filtered to only show AE signals due to cracking of the ice. This is the lower left corner of figure 4 expanded

As mentioned previously it was observed that OOP pencil lead breaks in the reservoir yielded LF-HF delta-T values of less than 50 and HF/LF ratios of less than 2. Figure 5 is a plot of the raw data in figure 4 as a function of LF-HF values below 50. Note that there are only a few signals recorded with HF/LF ratios greater than 2. IP pencil lead breaks (crack like signals) in the vicinity of the reservoir yielded HF/LF ratios greater than 2. Therefore if the modal ratio filter in the AESMART 2000 is set at 2 and the LF-HF delta-T filter is set between 0 and 50 microseconds (for our particular thickness of bar), the system would ignore the signals due to the cracking of ice and thermal effects and only record signals due to crack growth in the plate.

DISCUSSION OF RESULTS

The vast majority of AE signals recorded during this experiment were due to signals self generated by the transducer due to thermal effects. The signals recorded due to the cracking of ice are shown by the group of data near the ordinates of the plot in Figure 4. The thermal effect signals were of high frequency with no low frequency components and would have been recorded by traditional AE instrumentation which in most cases only operate in a single frequency range above 100 kHz. All of these signals would have been recorded in the data base of traditional AE systems and post test analysis of the data would attempt to eliminate these signals from the data base. In addition to the thermal effect signals, signals from the cracking of the ice would also be recorded. These signals produce plate waves having both high and low frequency components. If a traditional system is only operating in the high frequency range, the signal characteristics of the ice cracking would have the same characteristics as cracking in the plate, since both produce plate waves with high frequency components. It would therefore be impossible with post test analysis by traditional methods to determine the difference between cracking of the ice and crack growth in the plate.

The key to determining the difference between AE due to thermal effects and crack growth is first to determine if one is measuring a plate wave. Since plate waves have both high frequency and low frequency components which travel at different velocities, measuring the time difference (LF-HF) between these two components and coming up with a realistic value (based on the distance from the sensor to the source), one can determine if the signal received is a plate wave. We have shown in this experiment that cracking of ice produces plate waves. The next step in determining the difference between these signals and crack growth in the plate is to measure the modal ratio HF/LF. These experiments show that the cracking of ice produces a modal ratio which has a maximum value of 2 (figure 5) and appears as an out-of-plane (OOP) source. In-plane (IP) pencil lead breaks (crack like source) produce a value of 3 or greater depending on the depth in the plate where the pencil lead is broken.

CONCLUSION AND RECOMMENDATIONS

An AE sensor attached to the surface of a cryogenic vessel will itself produce signals during warming up and cooling down of the vessel. After the temperature is stabilized at a constant temperature these self induced signals usually cease. If they are present they can be eliminated from the AE data base in real time by LF-HF filtering and measuring of the Modal ratio HF/LF. It is also shown in this report that cracking of ice is an OOP source which produces plate waves than can be eliminated in real time by HF/LF Modal ratio filtering. A 6.45mm thick plate was used for this experiment. It is recommended that one perform pencil lead breaks on plates similar to the plate thickness of the vessel to be monitored, at distances up to ½ the spacing between transducers in order to determine the proper range to set the HF/LF modal ratio filter and HF-LF filter for the AESMART 2000 AE instrument.