I. Introduction

Ethanol-water mixtures are used for many purposes. The most obvious use for them is in distilled spirits. Drinks like bourbon and vodka are fundamentally mixtures of ethanol, EtOH, and water, while other physical and chemical properties come from the production process (ie. the color of bourbon comes from the barrel). The traditional method of measuring the alcohol content of a distilled spirit involves a floating hydrometer; however, the floating hydrometer is not very accurate. A standard floating glass hydrometer cannot get an accuracy of more than two or three gravity points (a common measurement for hydrometers). Floating hydrometers also frequently suffer from manufacturing errors.[1] Another method is to use a digital hydrometer, such as the Anton-Paar Snap 51. This gives a very accurate measurement to 0.1% v/v. However, the Snap-51 is almost $4,000.[2] A distilled spirits manufacturer must choose between cost-effectiveness and accuracy.

Another use of EtOH-water mixtures is in the calibration of ultrasound technology.[4] It is generally accepted that the sound speed, c through a solution of 9.6% EtOH at 20°C is 1540 m/s.[3] Thus having an accurate and cheap measurement of c through water would also help ultrasound technology.

II. Methods

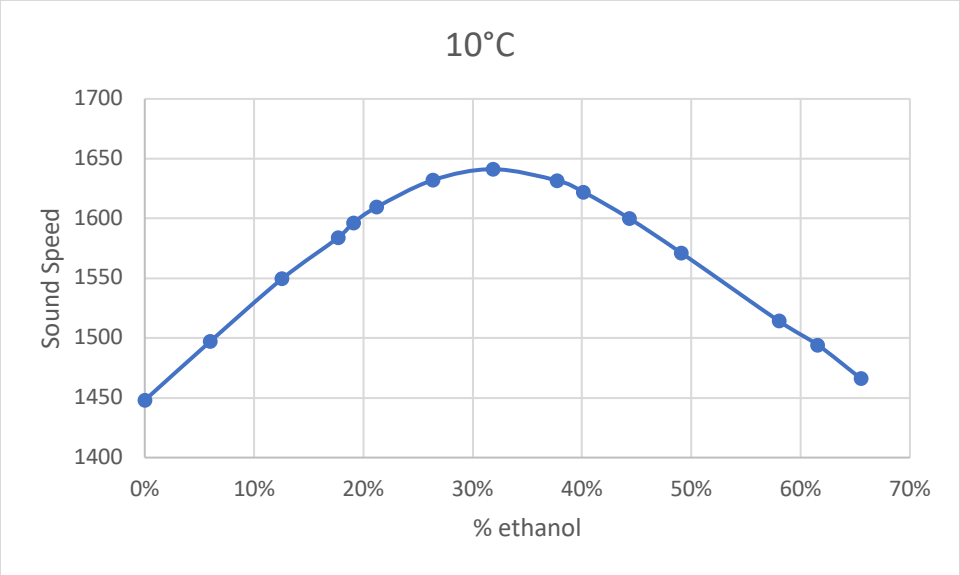
In this experiment, the Tektronix-AFG3022C sent a positive square pulse. In a solution of EtOH and water, two piezoelectric transducers were placed at a constant distance, d, apart. One was the source transducer, and the other was the receiver. The source transducer sent the square pulse to the receiver. The time of flight from the source to the receiver was measured. d was divided by the time of flight to determine the sound. The time of flight was measured at a range

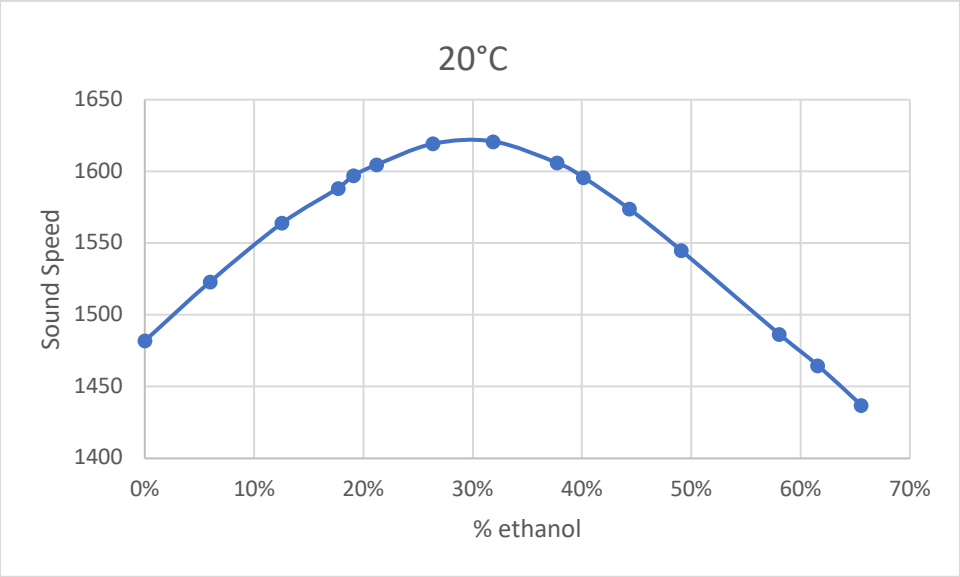
of temperatures Celsius, t for each solution. There were several solutions measured, with each having a different concentration of EtOH. The alcohol content was measured with the Snap-51.

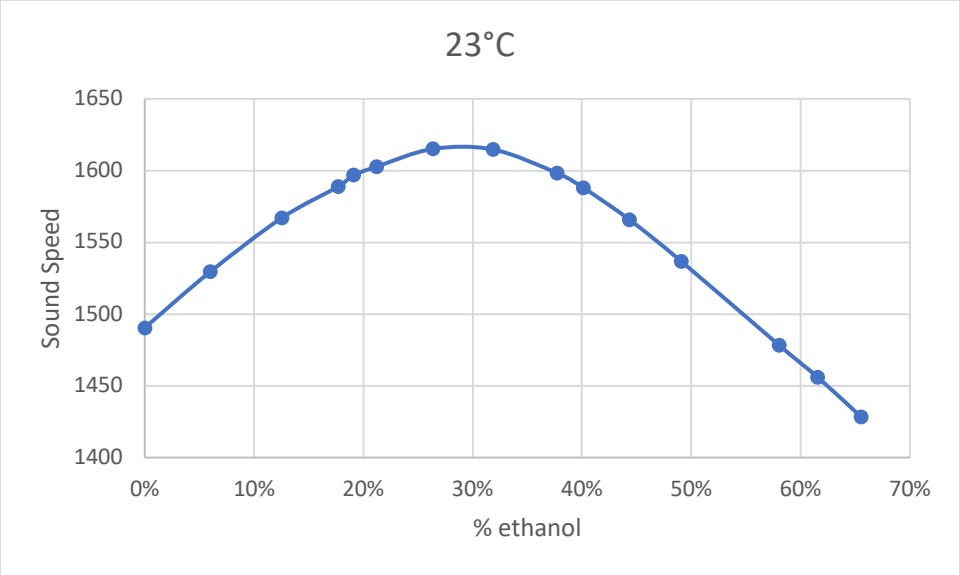
A device was created using Arduino hardware. The device uses the HC-SR04 ultrasonic distance sensor to measure the c, and the Waterproof DS18B2 to measure T. The values measured from the Arduino device are then transferred to excel, where they are put into a program that estimates the alcohol percentage.

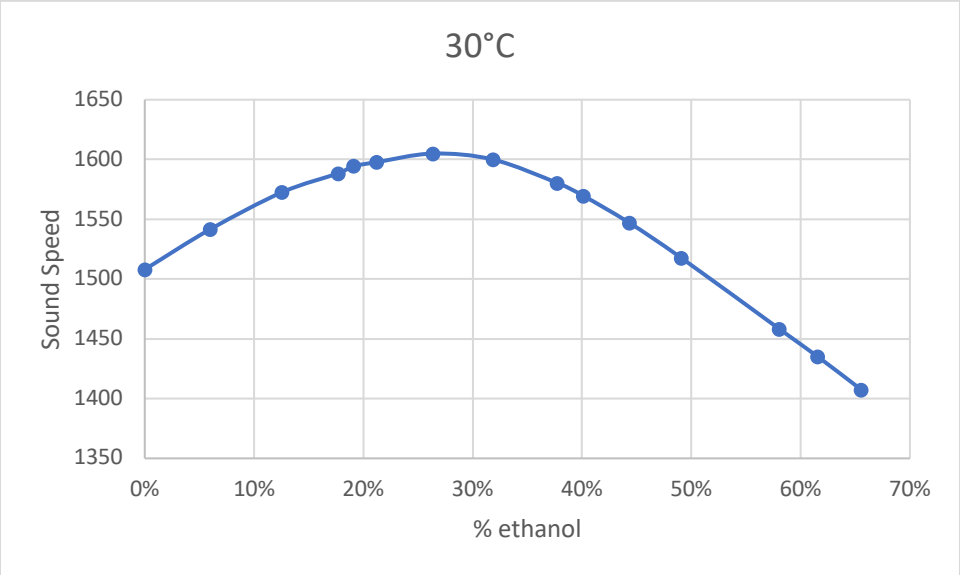
III. Results

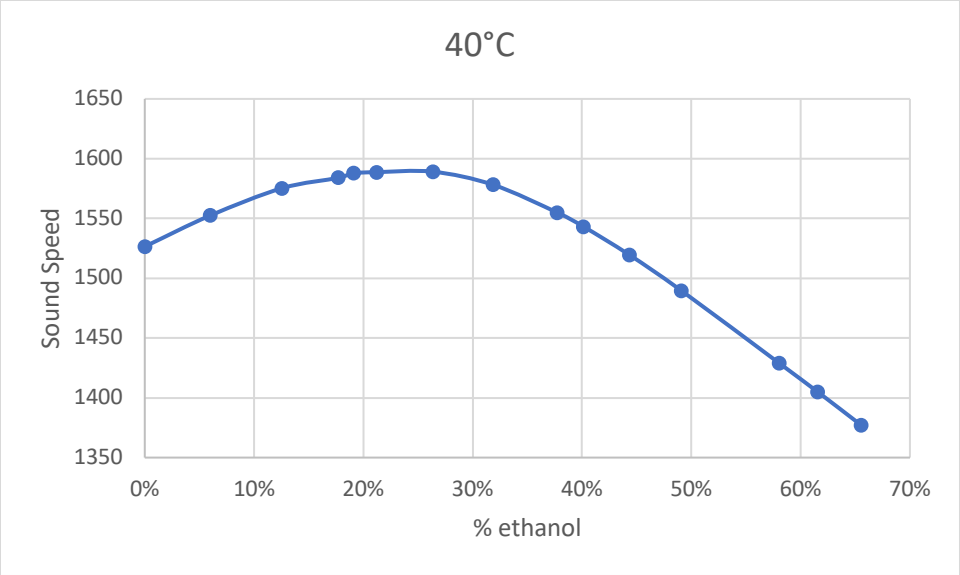
The experiment shows that the c in the EtOH /water mixture is strongly dependent on t of the solution and the EtOH concentration. The curves for a few t values and the graph for several t curves are as follows:

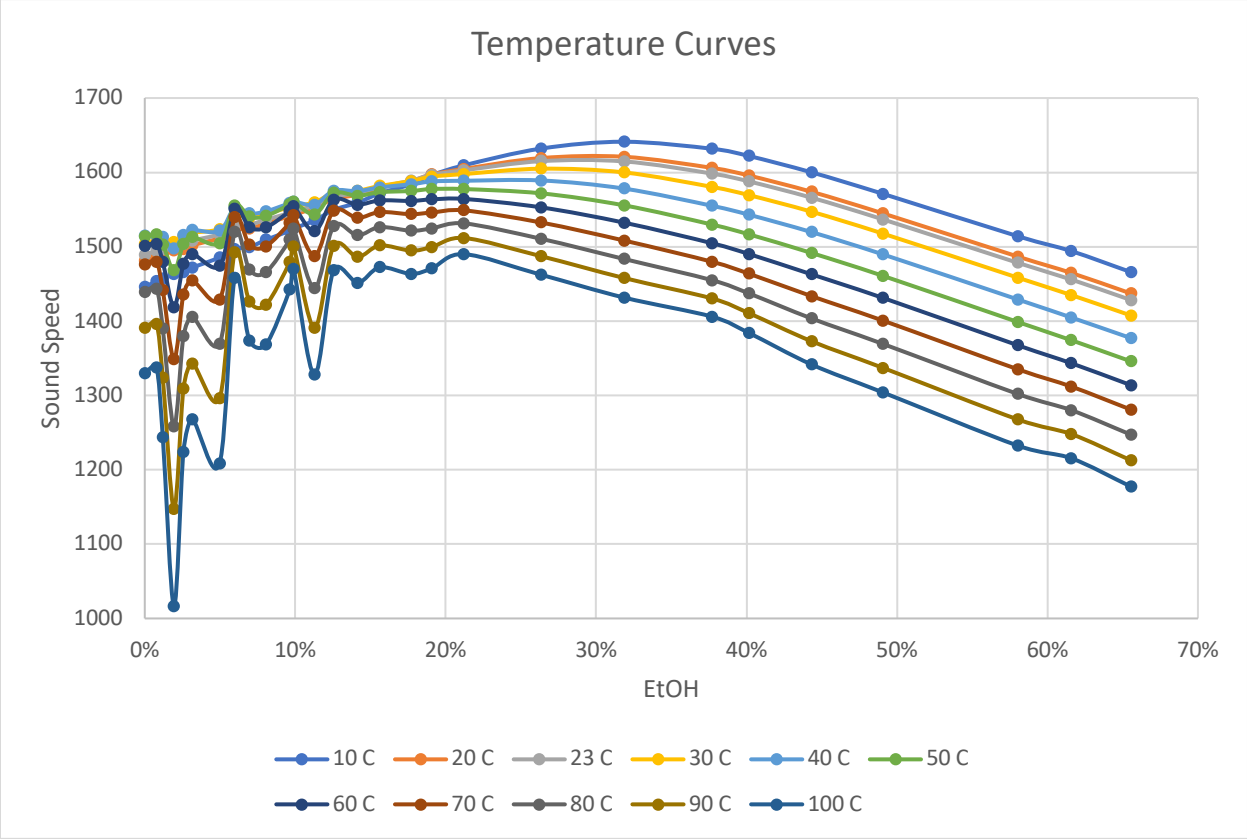

10°C
1700
1650
1600
1550
1500
1450
1400
Sound Speed
0%
10%
20%
30%
40%
50%
60%
70%
% ethanol


20°C
1650
1600
1550
1500
1450
1400
Sound Speed
0%
10%
20%
30%
40%
50%
60%
70%
% ethanol


23°C
Sound Speed
1650
1600
1550
1500
1450
1400
0%
10%
20%
30%
40%
50%
60%
70%
% ethanol


30°C
Sound Speed
1650
1600
1550
1500
1450
1400
1350
0%
10%
20%
30%
40%
50%
60%
70%
% ethanol





As can be seen, c increases with EtOH concentration to about 20-30%, depending on the temperature, EtOH concentration, where c peaks. From then on, c steadily decreases at a virtually linear

The device created using Arduino software can use c measurement to calculate the alcohol density of the solution. The values are put into an excel program which uses the t curves to calculate the EtOH percentage. There are listed in the spreadsheet every t curve from forty to one hundred in ascending by 0.1° F. The program finds the column of the correct t, and then finds the closest c value in that column. The program then finds the consecutive c value and then calculates the EtOH percentage between the two consecutive c values. The program only works with EtOH percentages of 40 and higher because 40% EtOH and higher is what makers of distilled spirits are concerned with. Above 40% the c curves are almost linear, which makes the EtOH percentage easy to calculate.

Discussion

The results of the experiment line up with previous research. The graph of 23°C was very close to the other curves in figure 6 of Jintamethasawat et al.'s article "Error analysis of speed of sound reconstruction in ultrasound limited angle transmission tomography".[4] If the t and c of an EtOH/water solution is known, then the EtOH percentage could be determined. A device using Arduino software can be made to measure c through EtOH-water mixtures. Makers of distilled spirits can use c to measure the alcohol content of spirits. More research needs to be done on the t curves for high t, low EtOH concentration mixtures. The t curves in this area do not line up well with the other curves. This deviation in the t curves would not interfere in the making of distilled spirits, as spirits have a high alcohol concentration and are generally not heated that much, nor are spirits low enough in alcohol content to be affected by the odd temperature curves.

Bibliography:

1. Brian Dixon, *Easy Calibration of Floating Glass Hydrometers*, https://www.morebeer.com/articles/Hydrometer_Calibration, (Accessed August 22, 2020).

2. Anton Paar, *Handheld Alcohol Meter: Snap*, https://www.anton-paar.com/us-en/products/details/snap/, (Accessed August 22, 2020).

3. Measurement of the speed of sound in ethanol/water mixtures, Kevin Martin and David Spinks, Ultrasound in Med. & Biol., Vol. 27, No. 2, pp. 289–291, 2001.

4. Error analysis of speed of sound reconstruction in ultrasound limited angle transmission tomography, Rungroj Jintamethasawat *et. al.* Ultrasonics **88** p. 174–184 (2018).