Development of Simulator for Calibration of Pulsed Instrumentation and Ultrasonic Characterization

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ABSTRACT

Simulators are important research tools widely used to imitate the behavior of some real entity or phenomenon. Researchers studying the acoustic behavior of different liquids and their mixtures make use of numerous instruments which are either purchased or designed. Purchased instruments are well calibrated or come with calibration standards. But it is not easy to calibrate in-house designed system, since there is no visual reference scheme available for comparison. In the present work, an attempt has been made to develop computer simulation software helpful in not only calibrating the instruments but also in study of the ultrasonic characteristics of liquids and liquid mixtures from the available standard database. The developed simulator was found to be effective, powerful and reliable for the calibration of various designed pulsed instrumentation in the laboratory.

Key words: Ultrasonics, simulator, software, calibration, pulse echo, sing around technique

INTRODUCTION

Simulators are computer tools used to mimic the behavior, functionality or performance of a real entity, phenomenon or system. Simulations are helpful in understanding and improving the quality of system design. It is a cheaper and safer means to study and often it is proved to be more realistic than traditional experiments, as it allows free configuration of environmental parameters in operational fields. Systems can be too complex or time

consuming, for them, simulation provides an approach which is simple and faster than the actual system.

Ultrasonic characterization plays a significant role in better understanding liquids and liquid mixtures. The characterization is based on a simple principle of physics: the motion of any wave will be affected by the medium through which it travels. Commonly studied properties of liquids are the velocity of sound wave through the medium it travels and amount of energy absorbed by the medium (attenuation). There are different standard techniques available such as sing around technique, pulse echo technique, optical techniques etc for this purpose. Based on these techniques, an instrument is design and developed. The basic functionality of these instruments is to generate ultrasonic wave, transmit it as a pulse and receive the reflected signals, generally referred as echoes, before transmitting the next pulse, then it is amplified and analyzed. The distance between the peaks of any two consecutive echoes is the distance traveled by the pulse, from which velocity of sound through the medium it travelled is calculated. The decreasing amplitude of each echo represents the amount of energy absorbed by the medium. It is worth to note that less attenuating liquids produce higher order of echoes while attenuating samples drastically reduce the energy in pulse, causing lesser number of echoes. In this way many conclusions can be drawn from such observed echo pattern, Fig 1. The output is generally seen on an oscilloscope or displayed on any digital media. A variety of commercial instrumentation is available for this purpose. Researchers in various laboratories design and develop their own ultrasonic system featuring different methods or techniques of calculating the parameters, specifically velocity and attenuation [1][2][3][4][5][6][7][8][9]. But they don't have a standard reference to verify the functionality and accuracy of their developed system.

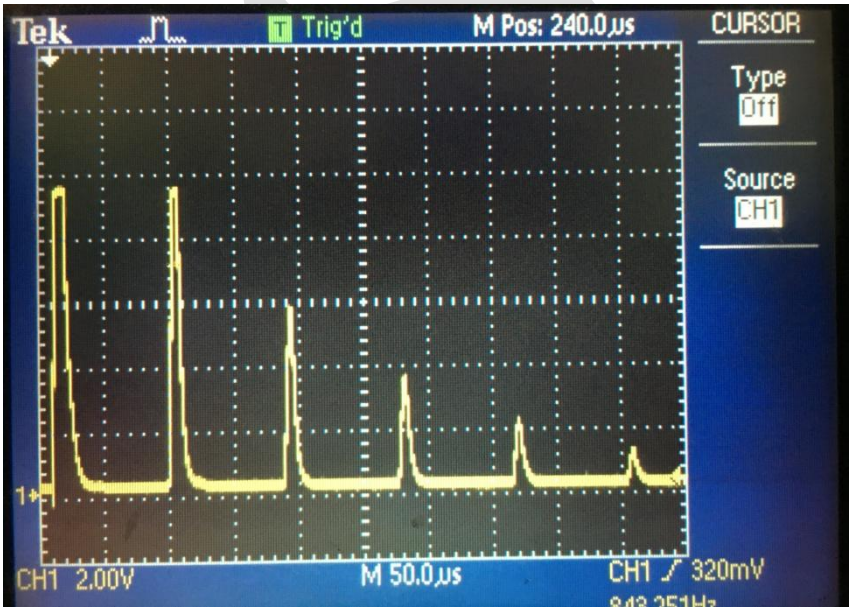

Fig 1. Observed Echo Pattern from a laboratory designed instrument

Branded instruments are generally pre-calibrated or come with manuals for calibration instructions. Researchers generally flip through literature data to check with standard data available to cross check with observed data taken using the designed instrument. Search for appropriate literature values is time consuming. Then the comparison between standard literature and observed data is done to verify the functionality of the instrument. It requires lot of calculations to arrive at a certain conclusion. All these calculations don't give visual

perception of echo pattern of sample under test. To get such visual perception using graph papers or excel sheets, again, huge calculations are required [10].
In present work, an attempt has been made to develop software to simulate the data of ultrasonic velocity and attenuation from the literature database and represent it in the form of graph showing the echo pattern and calculating the fundamental parameters such as velocity, attenuation and time-of-flight[11][12][13]. The software also helps to compare data from the designed instrument with the literature data visually.

FRAMEWORK OF THE SIMULATOR

Simulation is carried out on the basis of sample selection. The system in the present work has a small database for standard liquids, which is selected by user. Velocity and attenuation values mostly at room temperature are displayed. User needs to enter the path length and amplitude of first echo. Based on these inputs the pattern is generated and displayed as a graph. Also, amplitudes of each echo from the pattern are tabulated along with time-of-flight. Velocity of propagation is estimated from the path length of the sample holder and the time-of-flight[14].
If the user is performing experiment for the standard liquid, the simulator can plot the observed graph along with standard graph for comparison. For experimental observations, a user needs to enter the amplitude of each echo, path length and observed time-of-flight. Based on these inputs, the system computes the velocity and attenuation for the sample under test.
If both set of inputs are entered, then the system plots both the graphs for literature and experimental data so that user can compare it easily. If any deviation from the standard is observed, then a researcher can redesign/correct the system.

THE SOFTWARE

Software is developed using Microsoft Visual Basic 6.0. Visual Basic is GUI based event driven programming language [15]. It is a very user friendly language which also minimizes the system development time. It can also handle scientific calculations effectively. Moreover, it provides connectivity with database management systems such as Oracle or MySQL and can give access to I/O ports.

THE SYSTEM FUNCTIONALITY

The system takes inputs in four different ways. First, if the choice is distilled water, a record is selected on the basis of temperature, Fig 2a. It is selected from the drop down menu. On selection, velocity and attenuation at that temperature is displayed [16]. Second, if the record related to the sample under test is available into the database then the appropriate sample name is selected from the drop down menu, Fig 2b. Velocity and attenuation is displayed accordingly [17]. Third, if the sample under test is not listed into the database and if the literature values are available, then, there is a facility to enter the velocity and attenuation values for the unlisted sample based on which the value of attenuation coefficient, α (alpha), will be computed Fig 2c. Apart from this, amplitude of 1st echo is entered for simulation, based on the attenuation constant, other amplitudes are calculated. Also the path length of the sample holder is entered to calculate the travel time of the ultrasonic pulse. Finally, the experimental values which need to be compared with the literature values are entered [18]. The inputs are the measured amplitudes of each echo and the time-of-flight, Fig 4. It is possible to view the output from experimental and literature data individually. For comparison, they could be viewed simultaneously.
There is a facility provided in the present simulator to convert the values of ultrasonic attenuation reported in literature from nepers to dB/cm. Fig 5.

Fig 6a Shows the output echo pattern generated by the software. The graph area is designed to contain pattern generated from database and the observed echoes. Fig 6b. shows the amplitude of each echo generated by the software from the values of the sample from the database. The comparison of result is achieved by the calculated values of velocity and attenuation by the software, Fig 6c. Fig 7 shows the screenshot of the complete simulator software.

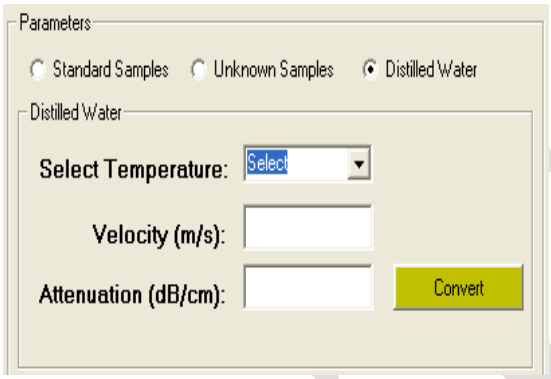

Fig 2a. Input screen for water

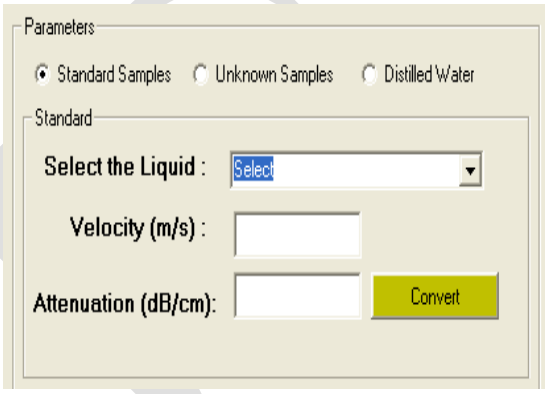

Fig 2b. Input screen for standard samples

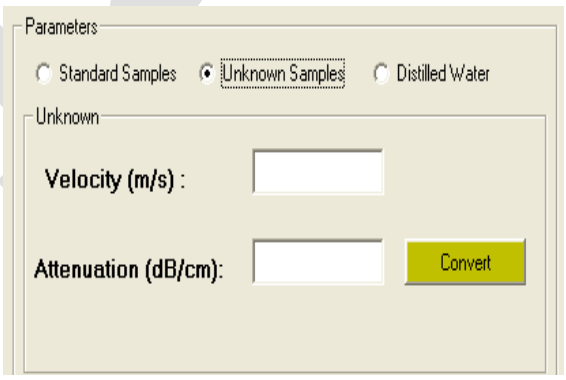

Fig 2c. Input screen for samples not listed in the database

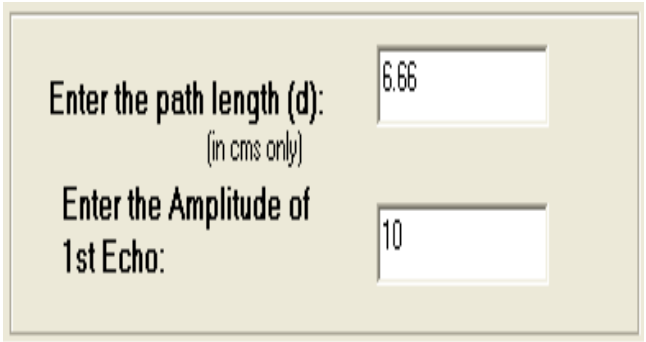

Fig 3. Input screen for path length and amplitude of first echo

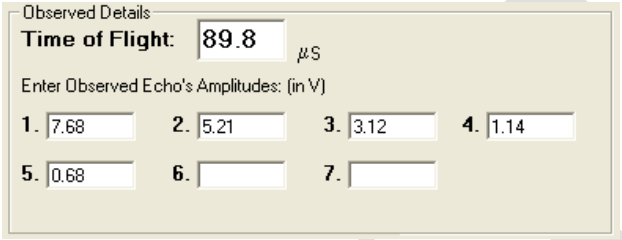

Fig 4. Observed details from the designed instrument

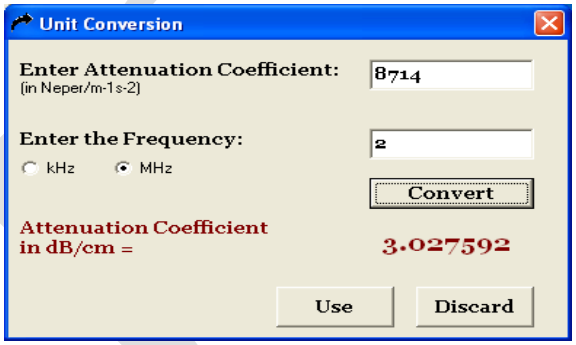

Fig 5. Attenuation Unit converter

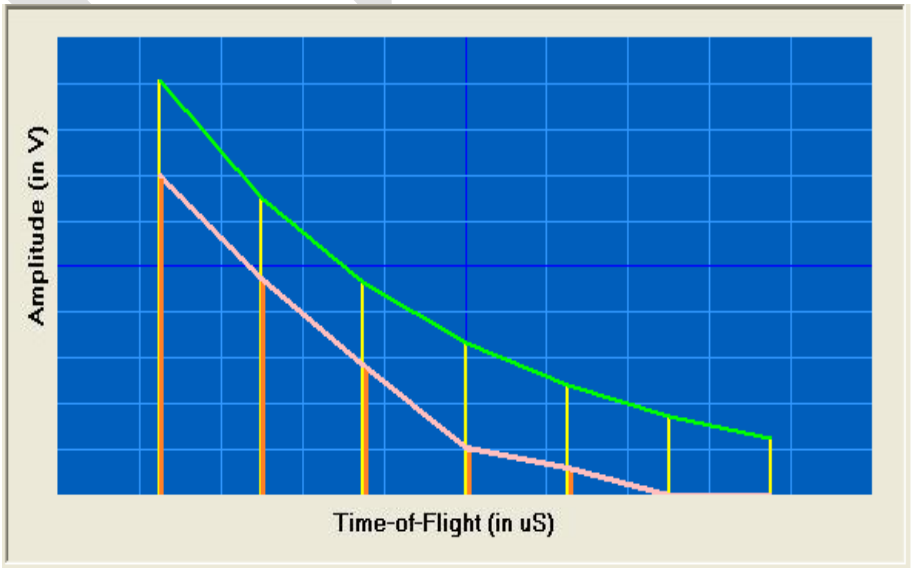

Fig 6a. Output graph for observed and standard data

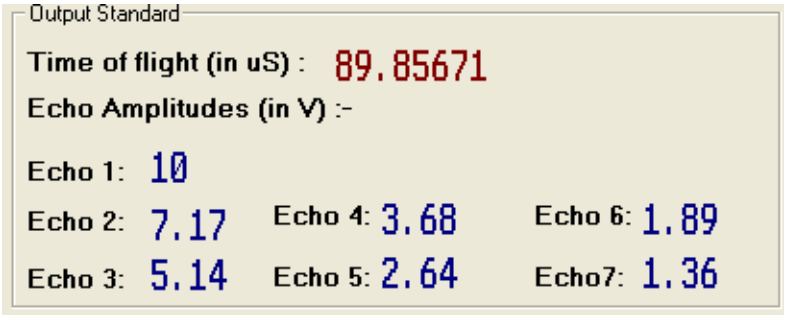

Fig 6b. Values of each echo generated by the software from the database

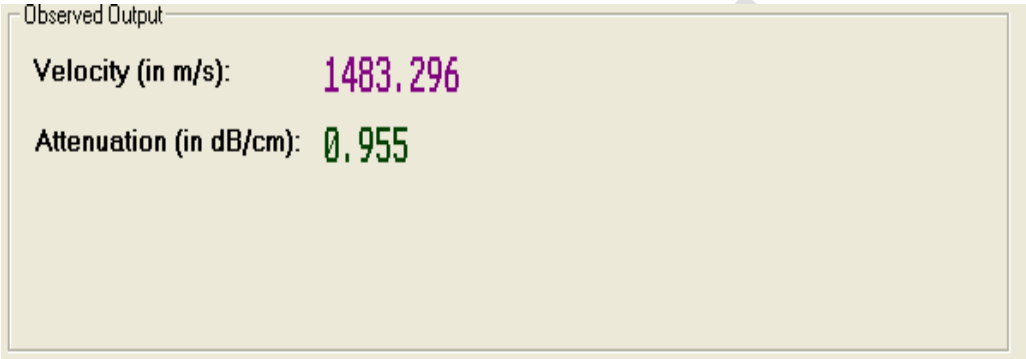

Fig 6c. Calculated values for observed data

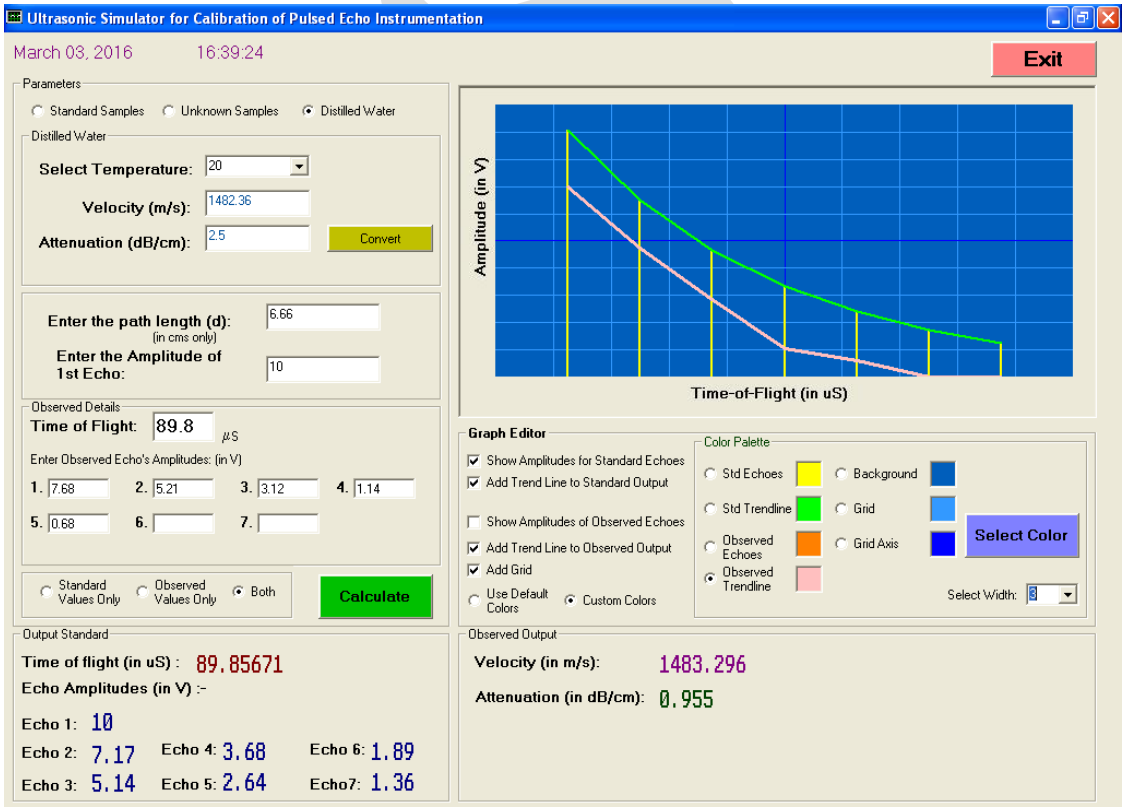

Fig 7. Screenshot of Simulator

SYSTEM FLOWCHART

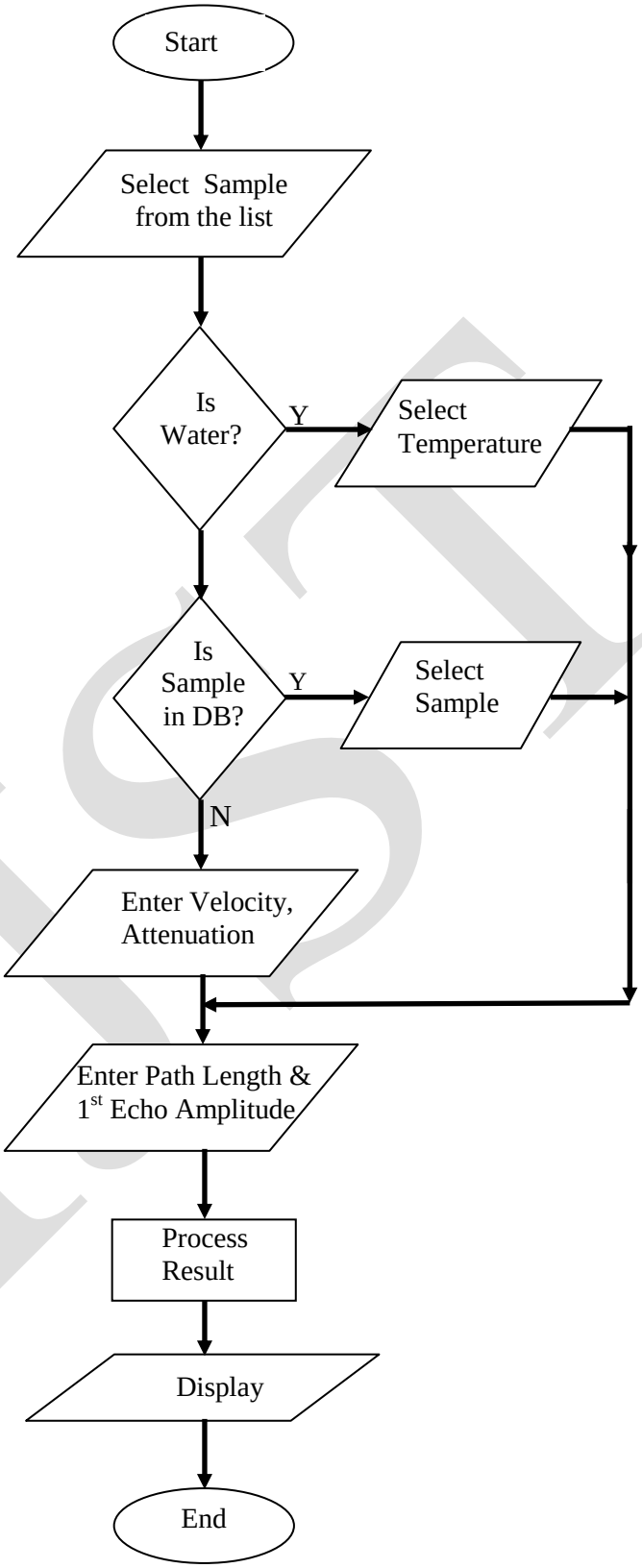

Fig 8: Simulation using Literature data

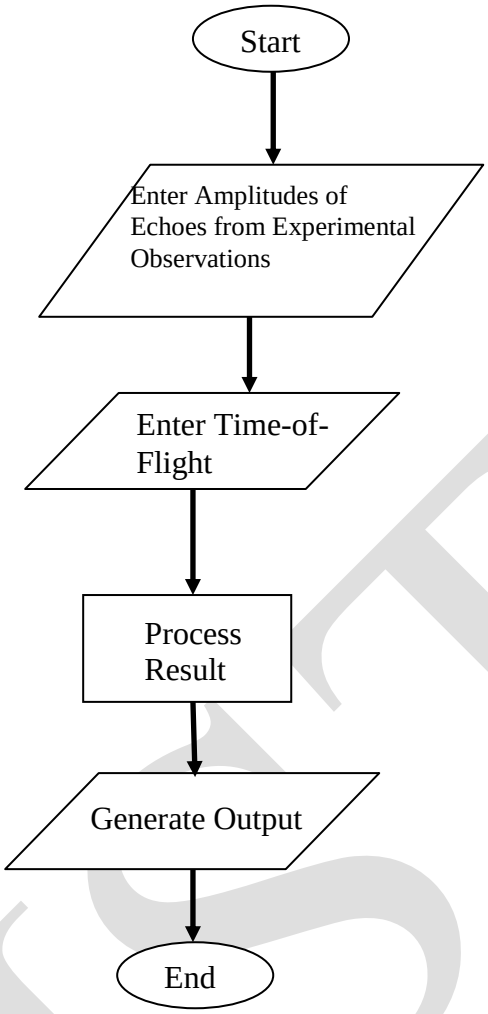

Fig 9: Simulation using Observed Data

RESULT AND DISCUSSION

Simulation software prototype for ultrasonic studies in liquid and liquid-liquid binary mixtures is developed to study fundamental characteristic properties of the medium under study such as velocity and attenuation. With successful implementation of this simulator, it can be further modified to study more parameters such as adiabatic compressibility, critical temperature and pressure, surface tension, velocity and attenuation at different temperatures and pressure, sea water - salinity etc. [19] With the help of ultrasonic echo pattern one can determine the absorption coefficient, viscosity etc.

Since, this software has few selected standard liquids stored in an array to form database to carry out the study, more simple liquids, associated and non associated liquids, critical mixtures can be added into the database in the form of separate tables for each categorized liquid since their parameters may not be the same. Also to study chemical parameters of the liquids or mixtures, a separate database could be maintained which has a collection of data

for molecular studies. This software could be made available online [20]. A registered user can add/modify the database to enrich the collection of liquids and mixtures and study can be taken to next level.

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