

# READING OF THERMOMETERS USING A VIDEO CAMERA

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*Abstract: In the proposed paper a possibility of automation of calibration of liquid-in-glass thermometers is discussed. Temperature readings are taken with the use of a measuring system that consists of a standard calibration facility, the video camera, and the personal computer that executes the program for image processing and analyses. Once the reading of temperature is extracted from an acquired image, this value can be passed to any other data processing, which includes the comparison with the values from the reference thermometer and determination of total uncertainty. Data achieved in this way can be directly used to prepare a calibration certificate.*

*Keywords: calibration automation, image processing, liquid-in-glass thermometers*

## 1 INTRODUCTION

Liquid-in-glass thermometers are still one of the most popular types of thermometers for use in industry and laboratory temperature measurements. The main reason for this is mainly the simplicity of their use, as it is possible to take temperature readings without any additional instruments except of course the human eye. Inability of automation is beside the mechanical fragility the main disadvantage of liquid-in-glass thermometers, but due to the specific use in industry, this usually doesn't create problems. If there is the need for an automatic measuring system, a different type of a thermometer is chosen.

On the other hand, a calibration laboratory has to calibrate liquid-in-glass thermometers too. Readings of temperatures are usually done manually. As liquid-in glass thermometers have only the visual interface, the only way to automate the reading of temperature is the use of a video camera. The simplest and commonly used method consists of just taking an image of a thermometer inside the calibration bath and then reading the temperature manually on a remote monitor. This method doesn't provide the level of automation that can be easily achieved when using other types of thermometers. It considerably simplifies the reading and if an appropriate magnification is applied, the reading error can be minimised, but the reading itself is still subjective estimation depending on a person, who takes it. Although this method represents a significant improvement, it is our goal to create a completely automated system for reading a temperature of liquid-in-glass thermometer that will be able to take an objective temperature reading with a personal computer, display it and process it for further use.

## 2 PRINCIPLE OF OPERATION

The basic principle of operation is shown in figure 1. A measuring system consists of a calibration, vision and processing section. The calibration section includes all components that are required in a normal calibration process, such as a calibration bath, a reference thermometer, etc. The vision section consists of a video camera and illumination. A video camera is usually a standard PAL or CCIR black & white analogue camera with appropriate lenses attached. Lenses must be carefully chosen in order to get a good magnification on a required distance from the thermometer under observation. One of the most important, but frequently neglected parts of the system is illumination. The first prerequisite for any image processing is an image with a good contrast and no undesired reflections and shadows, which can only be achieved by careful placement of a light source. The third section of a measuring system is the processing section, which consist of an image acquisition module and a personal computer. The image acquisition module converts an analogue video signal into digitised eight-bit greyscale images. These images are then transferred to a personal computer, where image processing and analyses take place. The resulting temperature values can then be used for the calibration purposes.

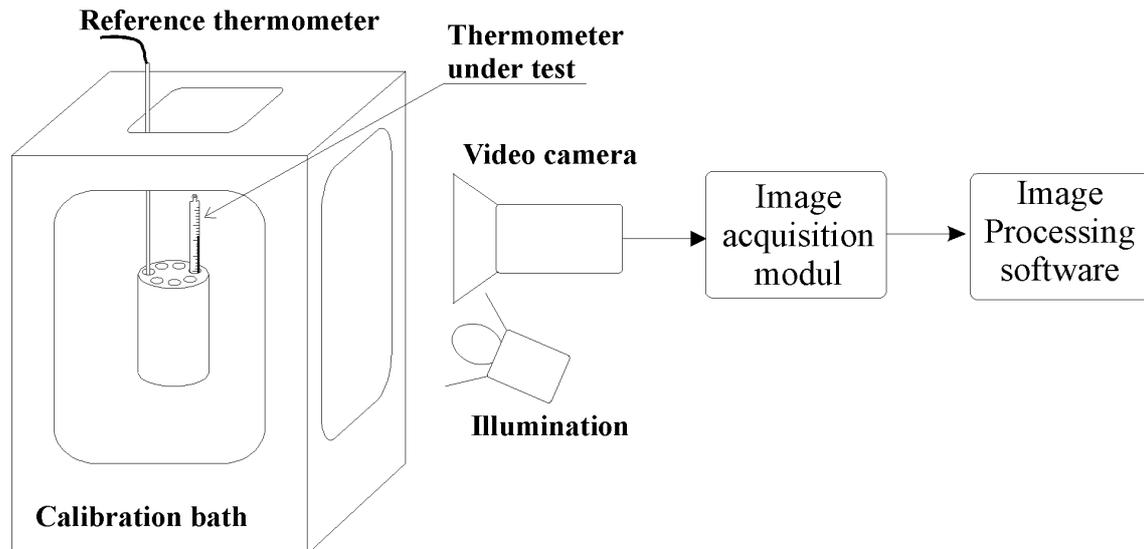


Figure 1. The structure of a measuring system for automated reading of liquid-in-glass thermometers

### 3 EXTRACTION OF THE TEMPERATURE READING FROM A THERMOMETER IMAGE

The program that determines the temperature reading from the acquired image of a liquid-in-glass thermometer is a key part of the entire application. The only input data for this program is the acquired image of a thermometer, Figure 2. When the thermometer is inserted into a calibration bath, a camera vertical position must be altered so that the top of the liquid column is visible in the image. Rotation of the thermometer is also necessary to make the column well visible, because most liquid-in-glass thermometers can only be read at a certain angle. Some other effects arise due to the fact that the thermometer is placed in liquid. In Figure 2 visible bubbles of water vapour have formed on the thermometer glass surface. If such bubbles form on a critical place, such as the top of the column, the reading is made very difficult.

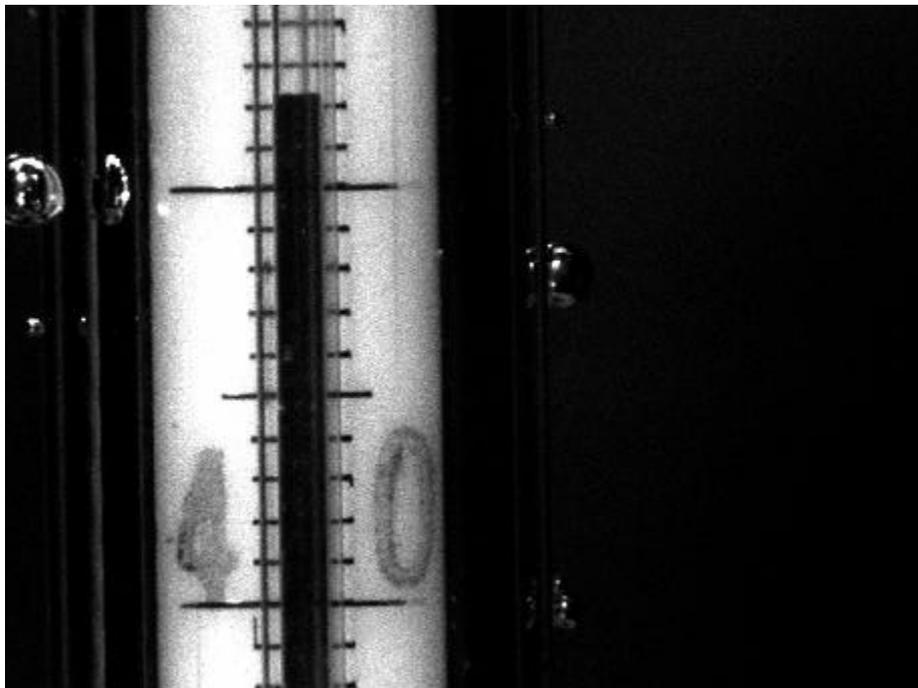
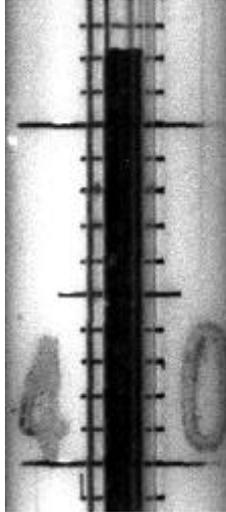


Figure 2. An original image acquired from a video camera

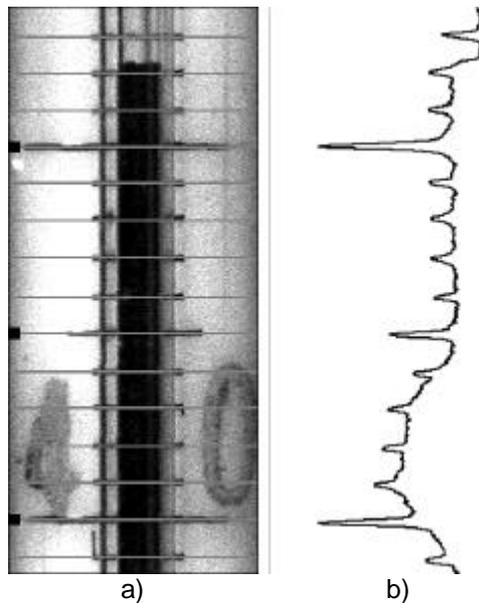
The program starts processing with location of the exact position of the thermometer on the image. If the thermometer is not in a strictly upright position, the necessary rotation is performed. This makes

the placement of the thermometer in a bath much more flexible. An input image can now be reduced to the image of the thermometer itself as seen in Figure 3.



**Figure 3.** A reduced image containing the image of the thermometer in an upright position

One of the most important parts of the program is the recognition of the thermometer scale. A lot of care is taken to determine the exact position of the individual scale divisions. If the recognition of some divisions is too ambiguous, the program ignores the information extracted from the image and interpolates the missing value based on the properly recognised divisions. A principle of the scale recognition is shown in Figure 4. A vertical profile of the image is calculated by averaging pixel values in each row. The resulting curve shows well visible valleys that match the position of each scale division. To recognise the thermometer scale must now find exact position and depth of each valley. Main scale divisions are recognised based on the depth of a valley that corresponds to the width of a scale division. To get the complete scale information it is necessary to manually type the scale resolution and the base of a thermometer scale, which is the temperature of the first major scale division in the image.



**Figure 4.** Recognition of a thermometer scale: a) the thermometer with recognised scale divisions. Main scale divisions are marked with black squares on the left hand side. b) the thermometer vertical profile.

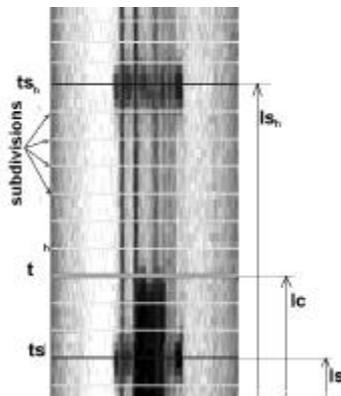
Temperature of a liquid-in-glass thermometer is determined by the length of the liquid column. To measure the length of the column the thermometer image is first horizontally reduced to the part where the column is positioned. Sophisticated digital filters are then applied to remove undesired objects such as scale divisions, scale numbers, random dark spots, etc. It is of importance that this filtering does not change the length of the column as this would directly result in the increase of the reading error. The result of this image processing is shown in Figure 5.a A vertical profile of this image is then calculated and the position of the step determines the length of the column, Figure 5.b Figure 5 clearly shows that although there are some minor irregularities (thin white strip at the left top of the column, etc), the step in vertical profile is clear enough to produce reliable reading.



**Figure 5.** Column width measurement: a) the thermometer column after image processing. b) the column vertical profile.

Once the position and the temperature value of an individual scale division and the position of the top of the column is determined, the temperature reading can be calculated using a simple interpolation equation, (1), where all quantities are presented in Figure 6.

$$t = ts_l + \frac{lc - ls_l}{ls_h - ls_l} * (ts_h - ts_l) \tag{1}$$



**Figure 6.** Zoomed area of an image showing the top of the column and two nearest scale divisions.

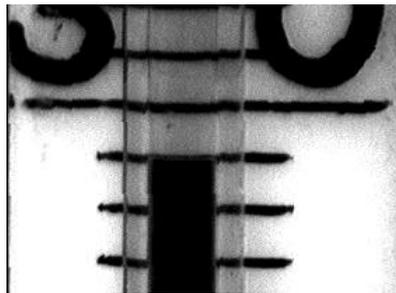
Figure 6 gives us a detailed view inside the area of interest. All values that were acquired from the image are displayed and ten subdivisions are drawn to make checking of reading easier.

#### 4 PROBLEMS AND ERRORS WITH THE AUTOMATED READING

Some problems and errors concerning the automated reading of liquid-in-glass thermometers were already described in previous chapters, especially those originating due to inappropriate illumination and placement of a thermometer. It is obvious, that if a video camera can't acquire a good image of the thermometer, further image processing can't give good results. But even if an acquired image is of a good quality, comparable to the one in Figure 2, some errors are still likely to appear.

Figure 6 shows magnified part of the image between two scale divisions. An image resolution is such that approximately 30 image pixels fit between two scale divisions. With subdivisions to help us with reading it might appear that the reading could be made at one tenth of a division or even better. But unfortunately this greyscale image doesn't show effects like parallax and meniscus, which can't be detected due to the limited camera spatial and colour resolution, but can be easily seen using other special optical devices, such as a microscope. These two effects make the uncertainty of reading bigger than one tenth of a scale division.

The biggest source of error and reading uncertainty however lies in the fact that the thermometer column and scale division lines are of almost the same greyscale level. This means that when the top of the liquid column reaches one scale division, software can't determine where exactly is the top of the column. Image processing that normally eliminates scale division lines is ineffective and reading is always placed at the upper edge of the scale division line. If the top of the column is positioned at the lower edge of the scale division line, the reading error becomes equal to the width of the scale division line, which is typically about one fifth of a scale division. This problem is illustrated in Figure 7. As there is almost no visual difference between the column and the scale division line, this error is very difficult to eliminate, but it can be very easily detected. If the reading is just above the scale division line than we can assume with a high probability that this error has occurred. If the reading is now corrected to the centre of a scale division, the uncertainty of reading is reduced from approximately  $+0.2$  to  $\pm 0.1$  of a scale division.



**Figure 7.** The reading error due to blending of the column and the scale division line.

Another problem that the automated reading has to face is a very large set of different thermometers. When a new thermometer is being read, some basic information has to be entered, including a vertical position of column, a column width, etc. Problems are likely to arise with thermometers with thin columns, Figure 8, where a column can be mismatched with some reflections on a glass stem and other image errors. This makes reading of such thermometers more difficult and less reliable.



**Figure 8.** Thermometer with a thin column

## 5 CONCLUSIONS

The proposed method gives the way to automate the calibration of liquid-in-glass thermometers. Automation of the calibration process reduces the time that operator spends for calibration and gives more objective and repeatable results. The uncertainty of reading can also be significantly improved down to one tenth of a scale division, if the described error of blending of a scale division line and a column can be eliminated. Otherwise the uncertainty of at least one fifth of a scale division can easily be reached. When readings are taken manually with human eyes only, the uncertainty of reading is amounted to a quarter of a division when the most care is taken. Of course, it is not the purpose of the proposed method to reach extremely good uncertainty of reading, but it is mainly focused on the simplification of the calibration. The program for temperature reading of liquid-in-glass thermometers can be easily integrated into a general calibration program that performs the control of the entire calibration process and can directly provide data for a calibration certificate.

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