MICROCOMPUTERIZED SYSTEM TO ASSESS THE PERFORMANCE OF INFANT INCUBATORS

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Abstract: This work presents a system based on a microcomputer to assess the performance of infant incubators in a semi-automatic manner. It carries out the tests described by the section 8 of the NBR IEC 601- 2-19 (1999). The developed electronic circuit acquires data from the sensors using a microcontroller. A set of sensors are used: five for temperature, one for humidity and one for air flow. The sampled data is sent to the PC via Bluetooth. The software running on the PC manages the data sampling, as well as guides the user through the test procedure by means of messages and sound alerts at the end of each stage. The sampled data is shown on the screen and also stored in a database that can be remotely accessed. The results are presented on a graph where the measurements (temperature, humidity and air flow) performed during the whole test can be seen. The procedure to calibrate the sensors and an infant incubator assessment carried out with the developed system is presented.

1 INTRODUCTION

There is a high percentage of mortality associated to low birth weight newborns (Ministério da Saúde, 2002). These neonates have an immature thermal control mechanism, preventing them to keep constant their body temperature (Gonzáles, 2001). The infant incubator (InI) aims to provide a thermo-neutral environment where the infant does not exchange heat, consuming a minimum amount of oxygen. This environment is obtained by controling the temperature, humidity and air flow. Inside the InI, the infant has a reduced metabolism that helps its healthier and faster growth (Ministério da Saúde, 2002). Therefore, InIs shall be periodically checked to assure that they offer a suitable environment to the neonate.

This work describes a system developed to assess the InI performance according to the Section 8 of the NBR IEC 601-2-19 (1999).

To evaluate the InI performance, the standard demands measurements of the following parameters: air temperature at five different points, relative humidity and air velocity. The temperature sensors are placed at five points 10 cm above the mattress surface (A, B, C, D and E) as shown in Figure 1.

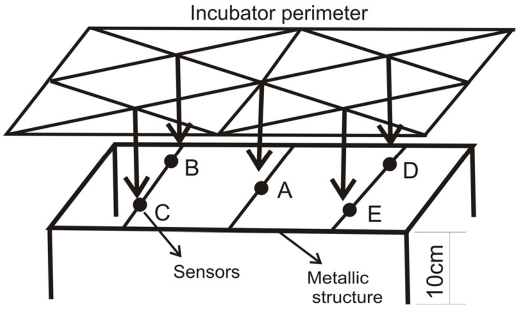

Figure 1: The NBR IEC 601-2-19 demands temperature measurements at 5 different points (10 cm above the mattress surface): A, B, C, D and E. A metallic structure is used to hold the sensors at the required positions.

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2 MATERIALS AND METHODS

The performance testing required by the standard is relatively difficult to be carried out manually, being desirable to automate it. Thus, a microcontrolled system was developed to automatically sample InI data that are sent to a microcomputer (Figure 2).

The developed system consists of 5 modules: sensors, acquisition, communication, control software and database.

The remote control software running on a PC communicates with the acquisition module to require samples from the sensors placed into the InI.

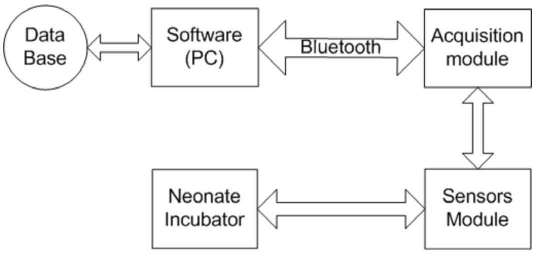

Figure 2: The developed system has five modules: sensor, acquisition, communication (Bluetooth), control software and database.

2.1 Sensors Module

The sensors are placed into the InI as shown by the Figure 1.

The sensor SHT75 (Sensirion Inc) is used to measure the Incubator Temperature (temperature at the point A of Figure 1) and the relative humidity (RH). It measures temperature in a range from -40 to 123.8°C and RH from 0 to 100%RH. For temperature, the SHT75 has a typical accuracy of ±0.5°C and resolution of 0.01°C. For humidity, typical accuracy of ±1.8%RH and resolution of 0.03%RH.

The measurements executed by the SHT75 are available in digital format via the 2-wire protocol. This is a bi-directional protocol, allowing the sensor to receive commands as well.

To measure the temperature at the other points (B, C, D and E), 4 TMP05 (Analog Devices) sensors are used. The TMP05 measures temperature in a range from -40 to 123.8°C with a typical accuracy of ±0.5°C and resolution of 0.01 °C.

The TMP05 sensors can be connected in cascade, establishing a net. Thus, only two microcontroller pins are needed to acquire the temperature measurements from the sensors: one generates a start pulse and the other receives the PWM signal.

The sensor F900 (Degree Controls Inc.) is used to measure the air velocity in the InI. It has a linear output voltage for a range from 0.15 to 2m/s with a typical accuracy of ±0.05m/s and resolution of 0.05m/s.

2.2 Acquisition Module

The acquisition module contains the microcontroller ADuC841 (Analog Devices) that has the following characteristics: 8052 core, 20 MIPS, 8 ADC channels (12 bits), 2 DAC channels (12 bits), 3 timers/counters (16 bits) and serial communication interfaces (UART, I2C and SPI).

The ADuC establishes serial communication with the SHT75 and TMP05 to get the humidity and temperature measurements. Its ADC samples the F900 voltage output to figure the air velocity out.

These measurements are sent to the PC when demanded by the control software.

2.3 Communication Module

The Bluetooth module implements wireless link between the acquisition module and the PC. To provide a communication range up to 100 meters, a KC-11 unit (KCWirefree) is connected to the acquisition module and a KC-210 is inserted into the PC USB port.

A virtual serial port driver is used by the control software to communicate with the KC-210.

2.4 Control Software Module

About 6 hours are necessary to carry out the measurements required by the NBR IEC 601-2-19 (1999). To simplify the task, a control software was developed for WindowsOS® in Borland C++ Builder.

At 20 second intervals, the software demands a new set of measurements. For that, an ASCII command is sent to the acquisition module. After receiving the command, the microcontroller communicates with the sensors to get the measurements that are sent back to the PC. The received data are presented on the PC screen and stored into a database.

Besides managing the measurements, the developed software guides the user through the testing procedure by means of messages and sound alerts at the end of each stage. The software displays messages on the PC screen asking the user to change the InI settings or the mattress position. After doing so, the user shall click the OK button of the message box. Then, the software keeps executing the measurements.

2.5 Database

The database (DB) was developed with PostgreSQL 8.0, a free software object-relational database management system (Matthew and Stones, 2005). The implemented DB has two entry tables, one registers the equipment identification key; the other stores the measurements carried out during the InI testing.

3 SENSORS CALIBRATION

The F900 and SHT75 sensors are individually calibrated. They both have calibration certificate. The F900 is supplied with its calibration curve. The SHT75 has calibration coefficients programmed into its internal memory.

The TMP05 sensors were calibrated using the SHT75 as reference since there was no other traceable reference sensor with better accuracy and resolution available in this laboratory.

To calibrate the four TMP05 sensors, they were placed together with the reference sensor into a container with low heat transmission walls. The air inside the container was heated up to 60ºC and then, the heat source was turned off. During the air cooling, 17 sets of temperature measurements were obtained for each sensor within the range from 25 to 41ºC. For each sensor, a third order polynomials was fitted to the experimental data to correct the systematic error observed with respect to the reference sensor. These polynomials are used by the software running on the PC to reduce the measurement errors.

To evaluate the described calibration, 3 measurements were executed for 13 different temperatures within the calibrated range to find out the resultant errors. This procedure was repeated for each sensor.

For each sensor, the systematic error (bias) and the random error (repeatability) were surveyed.

As example of the result achieved with this sensor calibration procedure, the Figure 3 shows the curves obtained for the sensor to be placed at the point E (Figure 1). This one presented the larger errors (about ± 0.5ºC) within the InI operating range (32 to 36ºC).

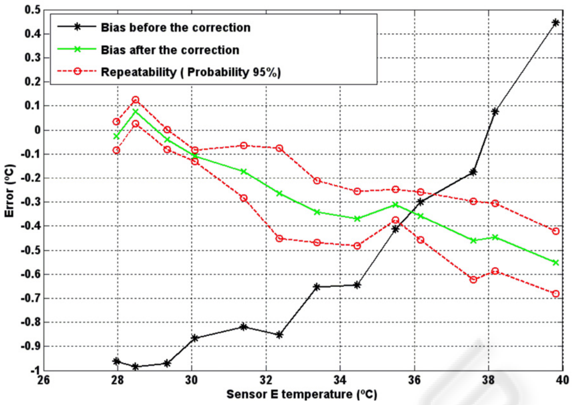

Figure 3: Measured error curve versus temperature is plotted for the sensor E. It is also shown the systematic error (before and after the application of the polynomial adjustment) and the random error.

4 RESULTS

To evaluate the performance of the developed system, assessment of an InI was carried out.

At the end of test, the results are stored in the DB. The results can be consulted on text format or graphically visualized. In text format, statements on the standard conformance are presented as shown in Figure 4.

For ethical reason, since the developed system was not certificated by an accredited laboratory, reference to the model and manufacturer of the InI as well as the health institution to which it belongs are omitted.

In the graph, the behaviour of the measured parameters (Incubator Temperature, RH and the air velocity) during the whole test can be observed.

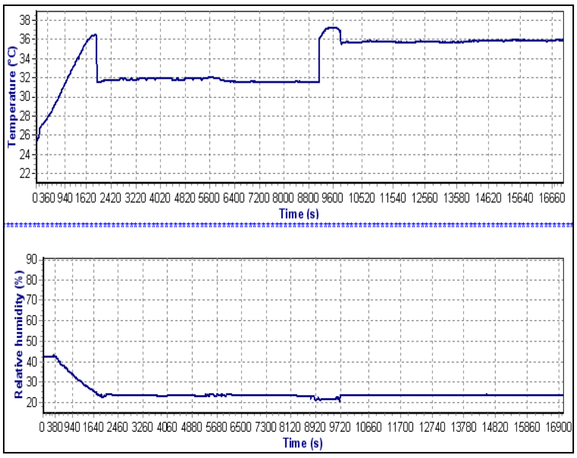

Figure 4: Incubator temperature measured during the assessment. Relative humidity and air flow curves are also presented in the graphical report.

ASSESSMENT REPORT FORM: INFANT INCUBATORS

EQUIPMENT DATA

HOSPITAL: **HOSPITAL**
MANUFACTURER: **MANUFACTURER**
MODEL: **MODEL**

DATE: **27/04/2007**
START TIME: **11:44:25**
END TIME: **18:16:39**

ASSESSMENT

STEP 1: LOCAL ENVIRONMENT TEMPERATURE
ADMISSIBLE RANGE: **21°C at 26°C.**
MEASURED TEMPERATURE: 25,40 °C.

STEP 2: TEMPERATURE RISING TIME TO ACHIEVE 11°C ABOVE THE LOCAL ENVIRONMENT ONE
MAXIMUM ALLOWED VALUE: **± 20% OF THE VALUE INDICATED BY THE INCUBATOR DATASHEET.**
MEASURED TIME: 31:10:01.

STEP 3: CONTROL TEMPERATURE OF 32°C -- MATTRESS IN THE HORIZONTAL POSITION.

DIFFERENCE BETWEEN THE INCUBATOR TEMPERATURE AND ITS AVERAGE ONE.
MAXIMUM ALLOWED VALUE: **± 0,5 °C.**
RESULT: IN CONFORMANCE WITH THE STANDARD.

DIFERENCE BETWEEN THE INCUBATOR AVERAGE TEMPERATURE AND AVERAGE TEMPERATURE AT B, C, D AND E.
MAXIMUM ALLOWED VALUE: **± 0,8°C.**
RESULT: NOT IN CONFORMANCE WITH THE STANDARD.

STEP 4: CONTROL TEMPERATURE OF 32°C -- INCLINED MATTRESS

DIFFERENCE BETWEEN THE INCUBATOR TEMPERATURE AND ITS AVERAGE TEMPERATURE.
MAXIMUM ALLOWED VALUE FOR THESE SETTINGS: **± 0,8 °C.**
RESULT: IN CONFORMANCE WITH THE STANDARD.

DIFERENCE BETWEEN THE INCUBATOR AVERAGE TEMPERATURE AND AVERAGE TEMPERATURE AT B, C, D AND E
MAXIMUM ALLOWED VALUE: **± 1°C.**
RESULT: NOT IN CONFORMANCE WITH THE STANDARD.

Figure 5: Part of the report generated by the developed system.

5 CONCLUSION

The developed system does not comprise a sound level meter. The sound measurements required by the standard are relatively simple to be made. Equipments available in the market can be employed to this end, having a layout that allows their use in other applications.

The maximum uncertainties in the temperature measurements (taking into account the propagation of the reference sensor uncertainty: ±0.3ºC) obtained with the sensors B, C, D and E are ±0.4 ºC, ±0.5 ºC, ±0.5 ºC and ± 0.61 ºC, respectively.

Assessment of InIs according to the NBR IEC 601-2-19 standard can be performed by the developed system in a semi-automatic manner, since the user has to change the InI operating settings during the test. Throughout the procedure, the control software beeps at the end of each stage and shows messages on the PC screen. These messages ask the operator to adjust the InI settings before performing the next set of measurements.

The control software and the used communication protocol have proven to be suitable and robust during the InI assessment.

The report generated at the end of the assessment points out the InI conformance with respect to the NBR IEC 601-2-19 requirements.

It shall be noted that all the tests carried out with an InI are stored in a same DB, allowing a better follow-up of its performance along its lifetime.

For instance, the number of corrective maintenance underwent by a given InI model can be very useful to the managers when considering the purchasing of new equipments.

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