# A REAL-TIME PREDICTIVE SCHEME FOR CONTROLLING HYGROTHERMAL CONDITIONS OF NEONATE INCUBATORS

**Gustavo H. C. Oliveira** [*,1] **Mardson F. Amorim** [**]
**Carlos Pacholok** [***]

** PPGEPS/CCET/PUCPR*
*Rua Imaculada Conceição 1155 - Zip Code 80215-901*
*Curitiba/PR/Brazil*
*e-mail: gustavo.oliveira@pucpr.br*
*** PPGTS/CCET/PUCPR*
*e-mail: mardson@ppgia.pucpr.br*
**** CCET/PUCPR*

Abstract: This work is focused on hygrothermal control problem of closed newborn incubators. Such incubator promotes a controlled micro-climate, with small heat transfer between the premature and the environment, which promotes a healthful environment. In this context, the main hygrothermal informations are temperature, relative humidity and partial vapor pressure where the last one is closed related with the water loss by transpiration. A model predictive control scheme for this problem is presented and real time closed-loop control examples validate the proposed method in such a context. The identification procedure, a need in model based control schemes, is based on the use Laguerre functions and the experiments are performed on a laboratory pilot plant (full scale) which was built to evaluate control algorithms in incubators. 

Keywords: predictive control, constrained control, system identification, orthonormal basis functions, neonatal incubators, hygrothermal conditions

## 1. INTRODUCTION

From many years, incubators have been used to create a comfortable and healthful hygrothermal environment for neonates. The aim of such device is to keep the respiratory and epidermal water losses at a small level and to increase the body heat storage.

In closed-type incubators, the internal temperature can be completely controlled. This property decreases the neonate temperature variance due to large differences between the air and the skin temperatures. An appropriate thermal environment decreases the rate of preterm infant morbidity and mortality. It has already been reported a reduction of 22% in such indexes by using incubators with temperature control (Perlstein *et al.* 1976).

Furthermore, another media of heat exchange between the neonate and its environment is the water loss through the skin and by respiration. When the incubator air temperature is constant, an increase in the air relative humidity (RH) value reduces the skin cooling and increases the body heat storage. Air RH values close to 65% prevents excessive body water loss and improves the maintenance of body temperature. The evaporation

[1] Author for correspondence.

rate when the air is at 60% RH is approximately 40% lower than that observed at a lower relative humidity (*e.g.*, 40%) (Telliez *et al.* 2001). Therefore, some incubators have active or passive systems to control the internal humidity. Control schemes, built to deal with this issue, have been described (Bouattoura *et al.* 1998) (Guler and Burunkaya 2002). In fact, by controlling the relative humidity and the temperature, one is actually controlling the internal partial vapor pressure . In an incubator, the partial vapor pressure value has an important role in the neonate water losses by skin and respiration.

From a control system point of view, an incubator is a system where temperature and RH values (consequently, the partial vapor pressure value) are the main controlled variables. Oliveira *et al.* (2005) presented an actual pilot plant built to simulate the micro-clime found in neonate incubators; and an application of multiple model control based on Laguerre functions modelling is also described. The results motivate real-time implementation of such control schemes.

The present work recalls some ideas discussed in (Oliveira *et al.* 2005) and extends such work by using a different predictive control law (*i.e.*, a scheme based on single models) and by presenting real-time results of such scheme in terms of by temperature, RH and partial vapor pressure control by the above mentioned pilot plant.

In the next section, some details of the incubator prototype are presented. In Section 3, important points related with orthonormal basis modelling are reviewed. This is the modelling approach used to represent the incubator. In Section 4, the predictive control law is described and, in Section 5, simulation examples of temperature and RH closed-loop control illustrate the performance of the discussed algorithm. Finally, conclusions are addressed.

## 2. PROCESS DESCRIPTION

In order to research issues related with incubators temperature and RH control and to test the results discussed in this paper, a neonatal incubator prototype was constructed and described in (Amorim *et al.* 2004, Oliveira *et al.* 2005). The main points related with such equipment are mentioned in this section. The pilot plant has the following parts: an acrylic transparent box (50cm height × 80cm length × 40cm width); a domestic heater, a fan and a humidifier. The heater and the humidifier are modified to allow external control in such a way that four power levels are available, that is: 0, 1, 2, 3 (or off, low, medium, maximum). The humidifier is based on ultrasound. The fan is on all the time. Ventilation ducts connect all the above-mentioned parts and allow air circulation inside the incubator. Fresh air supply is provided by the humidifier to guarantee some air renewal.

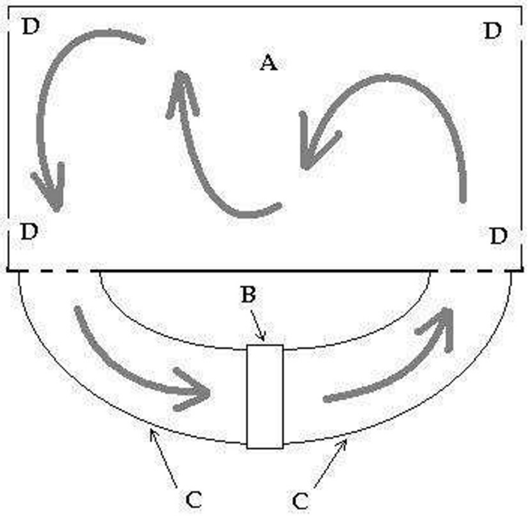


Fig. 1. Diagram with the main parts of the pilot plant.


Fig. 2. The neonatal incubator prototype.

The process diagram is presented in Figure 1. In this figure, the acrylic box is represented by (A), the heating and humidifying devices by (B), the fan is also in the position (B), the ducts that form a closed circuit are represented by (C) and the orifices that simulate open spaces for catheters, ducts, wires, sensors, etc are in the position (D).

Figure 2 contains an incubator photograph. In this photo, one can notice the acrylic box, the two inner temperature sensors and the two humidity sensors (two small black boxes), the electronic actuator device (it is below the acrylic box) and the ventilation ducts (they are behind the incubator). Some orifices are placed in the incubator's side to promote air changes.

The software environment for supervision and digital control is implemented by using the virtual instrumentation software LabView / National Instruments. The sampling frequency for temperature and RH signals is 2 Hz.