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PID Controlled Medical Fluid Heating System for Medical devices

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***Abstract*-- In some of the medical therapies performed on patient's which includes a medical fluid to treat the patient. It is very important to ensure that the temperature of medical fluid is about body temperature or 37°C with ±2°C. In cases where the temperature of the medical fluid is lower than that, cold cramps are felt by the patient and overheated has been reported as a cause of fatal hemolysis. Hence, the known systems for heating medical fluid have been less than ideal for a number of reasons. Some systems require large amounts of energy and higher temperatures, which can overheat the medical fluid if the flow of the medical fluid is stopped. This paper presents a method to achieve a temperature-controlled closed loop system using PID logic with heaters to achieve the desired temperature along with the flow path, ensuring there is no blockage or overheating the medical fluid. The controller controls all the operations by monitoring the sensor values, performing PID algorithms and ensuring the safety cut off for heater pads, along with maintaining the medical fluid temperature. By using more suitable and effective technologies, which enhances the medical aid by minimizing the therapy complexity. Experimental results shows that the outlet fluid has achieved the desired temperature with minimal rise time and error rate of ±2°C.**

Keywords—medical fluid heating, closed loop control systems, PID (proportional-integral-derivative), temperature monitoring and controlling, STM32 microcontroller.

I. INTRODUCTION

When a person's organ is no longer functioning properly, they may need to remove extra toxins, water, and other solutes from the blood. The medical fluid is a combination of water, electrolyte and salts like sodium and bicarbonate. During process, a patient's peritoneal cavity is filled with medical fluid using a catheter. The medical fluid and peritoneal membrane come into touch within the peritoneal cavity. By osmosis and diffusion, waste, poisons, and extra water are transferred from the patient's circulation into the medical fluid and through the peritoneal membrane. Waste, contaminants, and surplus water are removed from the patient by draining the medical fluid that has been utilized.

The peritoneum in a person's belly serves as the membrane, which exchanges fluid and dissolved materials with the blood. In patients with renal failure, it is used to remove extra fluid, fix electrolyte issues, and get rid of pollutants.

This paper work having the major concern for the medical dialysis system where medical fluid temperature rises by heating, the medical fluid needs to be heated roughly to body temperature or 37°C, before being delivered to patient. Where this proposed paper work has a heating system with closed loop control system and monitoring to achieve this case.

Where in therapy process which uses a solution, this solution is infused to patient. Prior to infusion of this medical fluid into patient the medical fluid will be at the temperature lower than the body temperature i.e., the temperature may be at room temperature are even colder. Filling this cold medical fluid directly into the patient's body while therapy process will cause the patients to feel discomfort. Thus, it is advised to heat the medical fluid to about body temperature or 37°C with ±2°C, prior to infusion into patient's body. Overheated medical fluid has been reported as a cause of fatal hemolysis, both acute and chronic. Underheated or cold medical fluid leads to cold cramps to the patient. Other process followed was to microwave heating of the medical fluid solutions. When microwave heating of medical fluid to 37°C produced focal overheating can be addressed as hot spots and caramelization of dextrose.

Controller used is a 32-bit up to 200Mhz Arm based controller. It has a capability to sense many more peripherals to control the entire medical device. Also, it is implied by the term "32-bit microcontroller" that the microcontroller can do arithmetic operations for a 32-bit number. The 32-bit microcontroller executes a function in less instruction cycles than an 8-bit microcontroller because of its wider data bus. when an 8-bit microcontroller cannot handle the program's code size. Flash memory is incorporated into 32-bit microcontrollers in greater capacities.

A group of mechanical and electrical components that automatically regulates the process variable to a desired state or set point without requiring human input is known as closed loop control system. This paper work have a closed loop with temperature sensor data which is read as input and processed, which is used to control the temperature of the fluid, which ensures flow of the fluid to achieve desired temperature, this is measured by the temperature sensor.

The fluid has to be maintained at the body temperature, as the temperature of the body is 37°c the fluid going inside the body need to be heated and should maintain the setpoint temperature thus fluid need to be heated up to 37°c this is done by the help of closed loop control systems logic and monitored by temperature sensors.

II. METHEDOLOGY APPLIED

The prescribed process delivers therapy to the patients as per the clinical prescription. The 4 temperature sensors are used to ensure the system meets the target set point for each cycle. The 4 temperature sensors are more commonly referred to as Heater Pad1 temperature Sensor (HP1_T), Heater pad2 temperature sensor (HP2_T), Input fluid temperature sensor (T_IN) and Output fluid temperature sensor (T_OUT). The 4 sensors input are considered along with software PID control loop to deliver the set point temperature with the defined accuracy.

The temperatures are increased by resistive plate heaters when electricity is applied, the heaters are in direct contact with the heater pads where the heater pads transfer the heat from the plate to the fluid which is in the cassette. As fluid passes through a disposable cassette that is in touch with the heater pads, heater plates heat the fluid. Because the fluid cassette has a membrane due to its material quality, it should not exceed the intended temperature. As a result, the temperature of the heater pads is restricted to acceptable limits, say a maximum temperature of 80°C for the fluid being heated. The heaters are positioned on the opposite side of the two heater pads, and the disposable cassette carrying the medical fluid is positioned in the space between the two heater pads.

See Fig 1, Representation of the disposable cassette, selecting a path for a medical fluid's flow when the fluid changes direction at least once per second. In the implementation it includes inlet and outlet for the medical fluid and the heater pads which is sized enough to hold the cassette and this heater pads are parallel to one another, where the fluid flows rapidly throughout the housing at a flowrate of 150ml/min and also including a protective insulating/plastic covering and a notch that permits the fluid flow to shift direction.

The processer is configured in such a way that it has to control the power and temperature based on the below parameters; those are: - i) An ideal temperature. ii) The medical fluid's flow rate. iii) The medicinal fluid's initial temperature. iv) The signals form the four temperature sensors.

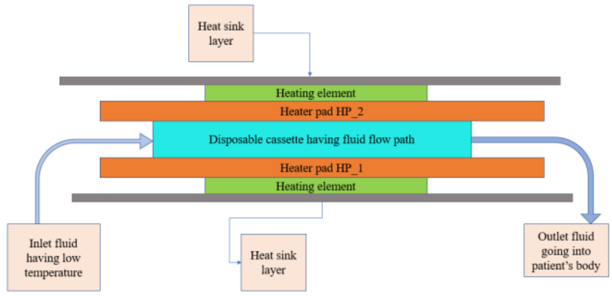

Fig 1:- Representation of heater setup

Where PWM signals from the controller are used to drive the power board, the power supplied to the power electronics is around one kilowatt, where it induces the current where it is used by the heaters to rise the temperatures.

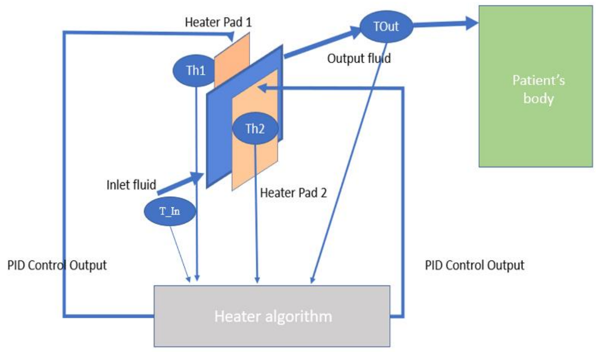

Fig 2: - Overall block diagram of the system

There are 2 NTC used one for each heater, they are named as Heater Pad1 (Th1) and Heater Pad2 (Th2). And other tow NTC sensors are output fluid temperature is measured at NTC T_out and inlet fluid temperature T_IN. All 4 temperature sensor data is taken as input to PID algorithm running on microcontroller. Output of the PID controlled is fed to the heater pad blocks to regulate the temperature of the output liquid. As per the output of PID logic the PWM signals are generated from the controller and this PWM signals are fed to the driver to induce current which further used to charge (heat) the heater.

The feedback loop of PID alters the feed-forward determination by taking a derivative gain, it increases the delta T utilized in a feedforward calculation if the value of the outlet temperature is too low, and decreases the delta T if the value of outlet temperature is too high. The heater responds fast to changes in fluid temperature or heating demands by heating up and cooling down; also, once the heaters reach the threshold temperature, the controller directs it to lower its temperature.

The closed loop control system should also ensure there is no excess heating of the liquid also. This closed loop can be implemented more effectively using PID logic controller.

III. EXPERIMENTAL DETAILS

Circuits for sensing the temperature of inlet fluid, outlet fluid in flow lines and heater pad temperature are designed using thermistor technology. The output signal is monitored and conditioned using PID logic and then fed to the MCU.

After establishing the setpoint, the feedforward unit and feedback loop are utilized to fine-tune the initial power setpoint to get rid of any discrepancy between the desired and actual fluid outlet temperatures. The PWM signal can be modified and one or more gains, such as proportional, integral, and derivative ("PID") gains, can be applied to the setpoint.

IV. RESULT AND DISCUSSION

The proposed method can be used to heat the medical fluid up to desired setpoint with ±2°C accuracy which is stored at low temperature. And all the temperature sensors are monitored throughout, and proposed paper have a PID controller to control the heat rate and ensure the fluid entering patients' body is about 37°C or body temperature.

It has an effective software implementation with a PID controller and a modified algorithm to achieve the stable fluid out temperature.

In the end of the results, able to achieve the minimal rise time, only ≤5% of percentage of overshoot and have an early settling point.

Initially the test has been conducted for inlet fluid temperature of 15°C see fig 3, where the desired outlet temperature archived is 36°C with minimal risetime and less over shoot, the test has been caried out for 8minutes cycle. Initially there was a high-rise time and overshoot with the modified algorithms and PID tunning minimal rise time and less overshoot is achieved. Different tests can be conducted on the proposed algorithm with different inlet fluid temperature to ensure the effectiveness and stability of the system.

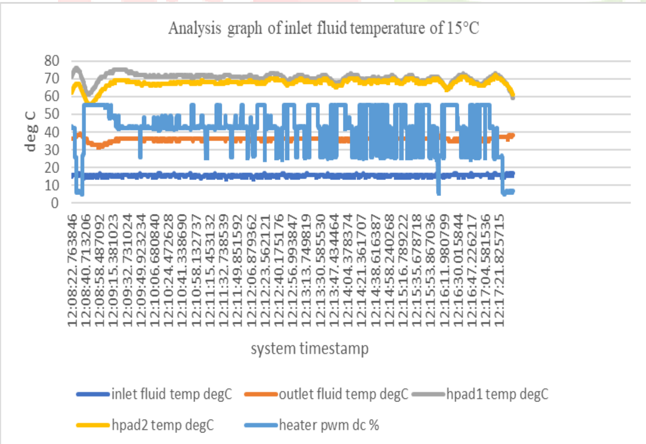

Fig 3: - Analysis of the temperature sensors output with T_IN temperature of 15°C

V. CONCLUSION

The main objective of the paper is to enhance the medical aid, improve the medical technology and minimize the therapy complications while performing therapy. in an implementation of the present paper work, a fluid heater for heating the medical fluid is provided. The heaters include the heaters where in the energy is directed towards the fluid, a controller operates on both the heaters to maintain a desired temperature. A need exists to provide more efficient medical fluid heater which is capable of heating relatively large medical fluid loads and which has an improved turn off response time. The purpose of having three different test is to determine which inlet temperature gives a most effective and appropriate results where all the three results give most effective results.

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