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ELECTRONIC SERVOCONTROL FOR WITHERING TROUGHS

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The design and development of an economically feasible electronic control system applicable to withering troughs is described. This system is capable of maintaining the drying capacity of air at 3°C ± 0.2°C.

INTRODUCTION

The main purpose of the withering operation in tea processing is to remove moisture from the tea leaf which will help to obtain leaf suitable for the next operation. If the atmosphere is dry enough, it can be used to remove moisture. When the atmosphere is humid, it is necesaary to heat the air slightly which will increase the drying capacity of air. The harvested green leaf is spread on withering troughs; two sets of louvers are available for each trough, which enables the operator to mix hot and cold air to get the required drying capacity.

The adjustment of these louvers has to be done carefully while measuring the hygrometric difference (hy-diff) and dry bulb temperature because an hy-diff of about 3°C and a dry bulb temperature less than 27°C is required to maintain tea quality without impairing it. Further the withering process demands about half the amount of heat energy required for the drying process. Therefore the correct adjustment of hot air intake will help to conserve considerable amount of heat energy.

However such adjustments become difficult due to operator errors which are common in nights and also due to inaccuracies of wet and dry bulb thermometers. These defects could be overcome only by installing an electronic servocontrol which is capable of adjusting the air flow to obtain optimum conditions for withering.

EXPERIMENTAL

Present method of operation

In order to design such a system the present method of operation has to be analysed.

1. When the hy-diff of air is above 3°C, only cold air can be passed to do the withering operation. Cold air louver is kept open and hot air louver is kept closed during this time. This is the case during daytime of most normal days.

2. In the evening when the hy-diff comes closer to zero, the burners are switched on. After about one hour, the hot air louvers are opened gradually till the hy-diff comes to 3°C, but without exceeding the dry bulb temperature of 27°C.

3. If the hy-diff of 3°C cannot be reached even when the hot air louver is fully opened, then the cold air louver can be slightly closed if the temperature is less than 27°C.

   When the cold air louver is slightly closed, the total air flow will be less and hence the drying, capacity of the flow (hy-diff times flow) will not change according to expectation. On the other hand passing air of hy-diff less than 3°C is not harmful; thus it has become a practice in most tea factories to keep the cold air louver open throughout the withering operation, which is acceptable.

Features of a suitable control system

From the foregoing the essential features of the proposed control system could be understood.

1. As the adjustment of the hot air louver alone is sufficient, a small reversible geared motor for each trough can be coupled to move the hot air louver wheel. However small reversible geared motors are quite expensive (Rs 20,000) and the development becomes uneconomical unless a low cost geared motor is found.

2. Standard mercury wet and dry bulb thermometers cannot be used to get suitable signals to a control system. Hence a suitable hymidity transducer has to be developed.

3. The characteristics of the withering trough, such as 'time lags' and accuracy demanded by the process have to be analysed before deciding the type of signal processing of the electronic design.

Development of the control system

1. **Low cost servomotor and linkages**

   The wind screen wiper motor of a motor vehicle is a geared motor which is capable of applying about 1/2 kg force that rotates at a speed suitable to the withering control system. The cost of a big 24V wiper motor is around Rs. 3,000. As the force applied by the motor on the hot air louver is sometimes not enough to rotate the shaft when the shaft is covered with tea dust the shaft has to be modified in order to obtain trouble free movement at any time during the operation. The available shaft of 10 turns was changed to 50 turns once in order to achieve this modification.

2. **Development of hymidity transducer**

   Two thermistors can be used as wet and dry bulb sensors. However normal low cost thermistors cannot be made wet as this also will change the electrical properties. Therefore two thermistors were placed in two test tubes and sealed with wax. In this method, a low cost hymidity transducer was made but there is a time delay of about 15 seconds in this method. However as there are other time-lags present in the withering trough, this lag has not given additional control system problems.

3. Characteristics of withering trough/Mode of control

A few preliminary tests and measurements were carried out to find the time-lag present in the withering process as these data are vital to decide on the signal processing of the control system. It is found that a time delay of ten seconds to two minutes is present between hot air louver movement to temperature variation under the trough. However the accuracy demanded by the withering process is about 0 ± 0.5° C and therefore advanced signal processing like PID control is not necessary. Therefore 'proportional mode' signal processing is considered to be sufficient for this design.

4. Development of Electronic Control Circuit

To reduce the oscillations which can be expected from this control system, a step type processing can also be included. In this method the motor was made to activate once every minute.
Two operational amplifiers are used to convert the sensor signal to two DC voltages representing hy-diff and dry bulb temperature. The actual hy-diff is compared with the required hy-diff of 3°C. The error signal coming out activates the motor driving circuit and its polarity decides the direction of motor movement. The magnitude of this error signal is also used to control the one minute oscillator above, and hence the hot air louver movement becomes proportional to the error signal. The magnitude of the dry bulb temperature is not used to control the oscillator but it is connected to a priority circuit which will make the motor to close the hot air louver, if the temperature is above 27°C but independent to the hy-diff.

As in any other servocontrol, two limit switches are connected to limit the hot air louver movement. This could be conveniently done by using the existing louver indicator of the trough. In order to monitor the conditions of the system four Light Emitting Diodes are connected to the circuit to indicate whether the temperature and hy-diff is above or below 27°C or 3°C respectively.

Experiments using the control system

The control system developed as explained above was tested using Trough No. 1 at St Coombs factory, Talawakele in November 1989. The hymidity sensor was suspended under the trough and three wires were used to take this signal to the system. An accurate wet and dry bulb thermometer and a stop watch were used to take measurements.

Experiment 1

The maximum allowable temperature was set to 26.3°C and the required hy-diff to 3°C. The hot air louver was fully closed manually and the control system was turned ON. Temperatures and indicators were observed every minute (Table 1). In the table the indicator 'L' means that it was ON when the LED showing hy-diff was low and 'H' means that it was ON when the LED showing it was high. When both LEDs are OFF the hy-diff is close to the set point and is indicated by 'X'.

Experiment 2

Another set of readings were taken similar to Experiment 1 but after giving an initial condition of 'hot air louver fully open' (Table 2).

The variation of Hy-diff in the withering trough is shown in Fig. 1.

TABLE 1 – *Wet and dry bulb temperatures with initial conditions hot air louver fully closed, set maximum temperature 26.3°C, and set hy-diff 3°C*

Time (min)	0	1	2	3	4	5	6	7
Temp (dry)°C	22.2	22.4	22.7	22.8	23.0	23.8	23.9	24.3
Temp (wet)°C	20.0	20.0	20.3	20.4	20.7	21.0	21.2	21.3
Hy-diff °C	2.2	2.4	2.4	2.4	2.3	2.8	2.7	3.0
Indicator	L	L	L	L	L	L	L	X

Time (min)	8	9	10	11	12	13	14	15
Temp (dry)°C	24.7	24.8	25.0	25.0	25.0	24.8	24.6	24.4
Temp (wet)°C	21.5	21.5	21.6	21.6	21.6	21.4	21.3	21.2
Hy-diff °C	3.2	3.3	3.4	3.4	3.4	3.4	3.3	3.2
Indicator	X	X	H	H	H	H	X	X

Time (min)	16	17	18	19	20	21	22
Temp (dry)°C	24.0	24.2	24.0	24.1	24.3	24.4	24.4
Temp (wet)°C	21.2	21.1	21.2	21.2	21.2	21.2	21.2
Hy-diff °C	2.8	3.1	2.8	2.9	3.1	3.2	3.2
Indicator	X	X	L	L	X	X	X

TABLE 2 – *Wet and dry bulb temperature with initial conditions hot air louver fully opened, set maximum temperature 26.3°C, and set hy-diff 3°C*

Time (min)	0	1	2	3	4	5	6	7	8
Temp (dry)°C	25.7	25.8	25.2	25.3	24.8	24.9	24.4	24.4	24.0
Temp (wet)°C	21.4	21.1	21.1	21.0	21.1	21.1	21.1	20.8	20.8
Hy-diff °C	4.3	4.4	4.0	4.3	3.7	3.8	3.3	3.6	3.2
Indicator	H	H	H	H	H	H	H	H	X

Time (min)	9	10	11	12	13	14	15	16
Temp (dry)°C	23.7	23.5	23.3	23.0	23.3	23.1	23.4	23.4
Temp (wet)°C	20.5	20.5	20.3	23.0	23.3	23.1	23.4	23.4
Hy-diff °C	3.2	3.0	3.0	2.7	3.0	2.6	3.2	2.9
Indicator	X	L	L	L	L	L	L	L

Time (min)	17	18	19	20	21	22
Temp (dry)°C	24.0	23.8	24.0	24.0	24.1	24.1
Temp (wet)°C	20.9	20.9	20.8	20.9	20.9	21.0
Hy-diff °C	3.1	2.9	3.2	3.1	3.2	3.1
Indicator	X	X	X	X	X	X

RESULTS AND DISCUSSION

From Figure 1 it is clear that the control system is keeping the hy-diff closer to 3°C. In the case of 'hot air louver fully closed' the hy-diff comes closer to 3°C within about 6 minutes and in the case of 'hot air louver fully open' within ten minutes. As these extreme conditions do not occur in practice, the response of the system is quite acceptable.

The system also stops tea from over burning as the maximum dry bulb temperature was set at 26.3°C. This action can be tested when the hy-diff is less than 3°C and the dry bulb temperature is above 26.3°C. This atmospheric condition cannot be expected at Talawakele, but the laboratory tests have shown that the system responds correctly under this situation.

When automatic louver controls are fitted to all troughs in a tea factory, it will help to get the correct amount of hot air from the driers and distribute it evenly to all the troughs which cannot be expected with manual control. When the correct amount of hot air is taken for withering, it is possible to reduce the fuel intake of the burners manually and save on fuel. This part also can be automated by fixing a thermostat control to the burner and sensor fitted outside the drier or at the hot air inlet of trough.

The cost of the above withering control system which was developed for a single trough was Rs. 6,000 including installation costs. Therefore a medium sized tea factory with eight troughs could install a system within a cost input of Rs. 50,000.

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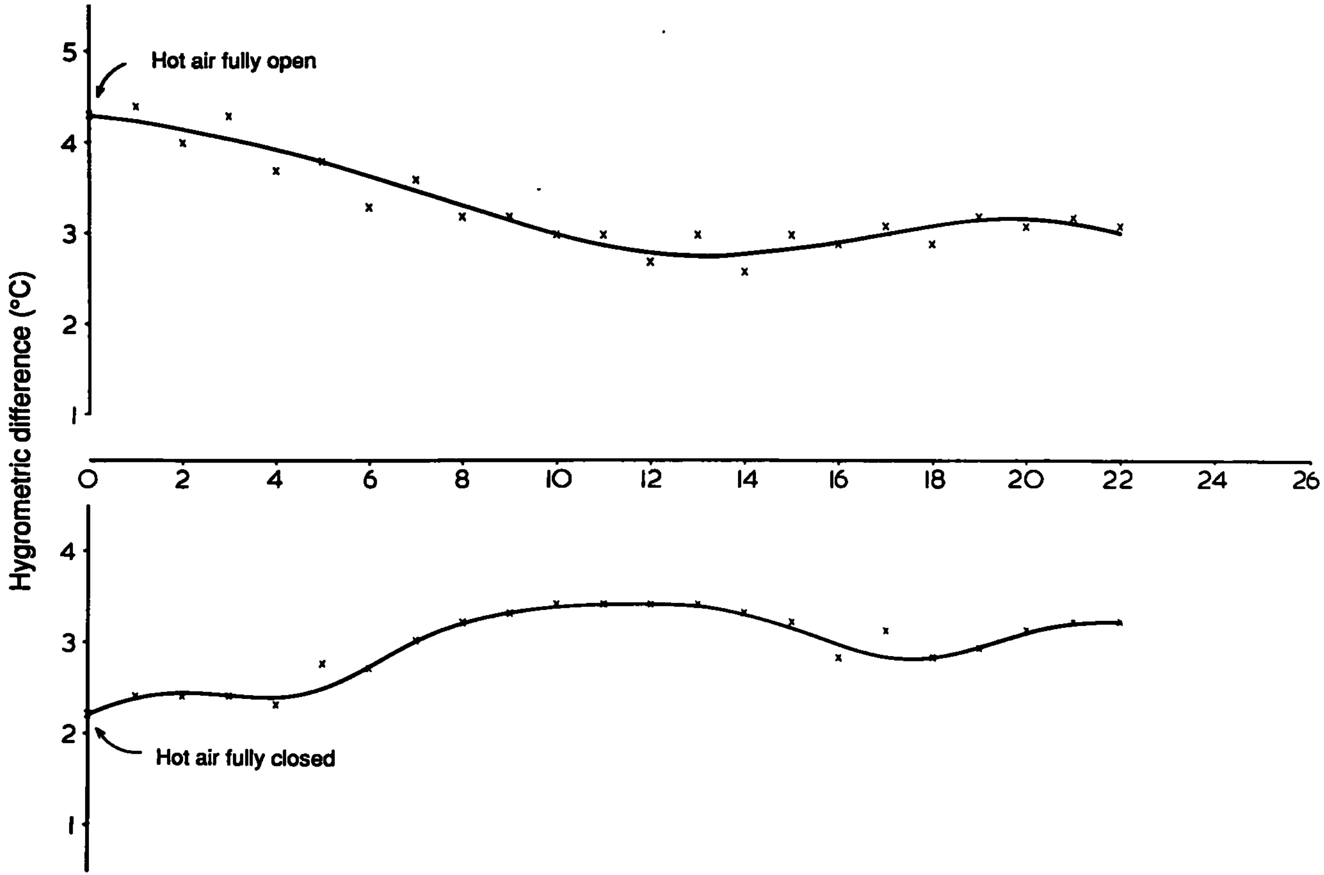

Fig. 1 – *Variation of Hy-diff with time with auto louver control*