ON THE THEORY OF WATER EVAPORATION AND ITS APPLICATION TO WITHERING AND DRYING OF TEA.—Part II

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In view of the foregoing,* the problem of control of drying should not be very difficult to solve, and without touching all possibilities I will directly describe the method which I consider most rational.

Primarily, the controls should be completely automatic. Nobody in a tea factory will take the trouble to look after conditions in the dryer continuously. It must therefore be possible to run the dryer without any supervision whatever, the only human element being the man who carries the leaf to the dryer; and even he could be done away with by installing a conveyor. Then the tea could be fed into the dryer continuously, or intermittingly as necessitated by the organisation of the factory, and the dryer would not only adjust itself to the wetness of the leaf, but also turn out tea with a practically constant moisture content; it would stop when no leaf is fed in and start again immediately leaf is supplied. Without going into details as to how this is achieved I would state that it can be done for any type of dryer, but that electrical drying lends itself more freely to this type of control.

In an automatically controlled dryer there would be three points of control; the first point to control the conditions of the air entering the air heater, the second to control the condition of the air between the air heater and the dryer proper, and the third one to control the condition of the exit air. The first point of control is not always necessary, and I shall omit it from this consideration. The second point of control is used to control the temperature or the drying potential of the air that enters the drying chamber proper; control of drying potential is, however, more complicated than control of

* See Part I in *Tea Quarterly* VI, pp. 67-77.

temperature. The third control is made to control the exit temperature or its drying potential. When one of the points controls the temperature, the other should control the drying potential.

It has been suggested that the third point of control should be placed under the first or second tray from the top instead of at the exit. The air that passes the former point however is not able to tell the full story of the drying process, and such a control will be less accurate than one in the exit. The reasons put forward for placing the control underneath the trays are that the leaf at this point has been heated up by the air, and that the drying process is not fully under way up to this point. The heating up of the leaf only absorbs from 1 to 2 per cent. of the total heat used in the drying and is of no importance, since that loss has hardly any influence upon the condition of the air whatever. Furthermore, it is very simple to prove that more water is evaporated from the two top trays than from any other tray in the dryer. Another reason urged for putting the control below the trays is that a control there would prevent stewing. It is obvious from what has been stated earlier that no temperature in itself can prevent stewing. However, with the double control as outlined above, the temperature of the air at any point inside the dryer can be easily maintained at a definite level should it be desirable to do so.

The temperature of the air entering the drying chamber can be controlled (second control point) by a device which will vary the number of B.T.U's that enter the drying chamber proper with the air, or better still, by one which will vary the amount of heat dissipated into the air in the air heater, i.e., one which controls the amount of fuel or electricity consumed. When the dryer is empty, this control would close down the air heater, and give only sufficient heat to keep the dryer warm until new leaf is put in.

The third control would be effected by a device to vary the amount of air or the amount of leaf that passes through the dryer, or to vary the composition or the elastic force of vapour of the air that enters the dryer chamber proper.

These two controls, i.e. the second and third, would co-operate; the third control would immediately signal to the second control when the top tray became empty or when dry leaf entered the dryer. The third control would then, for instance, shut off a certain amount of the air, and the second control would in consequence decrease the heat dissipated into that air, always keeping its temperature constant at the point of entry into the drying chamber proper.

I have dealt within the problem of control without going into mechanical details. I do not believe that a great improvement in the present control can be achieved without converting the dryers into fully automatic machines.

THE PHYSICAL WITHER OF TEA

Although the wither takes place at a considerably lower temperature than the drying, there is in principle very little difference between the two processes, the main difference being that the leaf during withering is nearly in equilibrium with the air surrounding it throughout the whole process.

So long as the leaf carries surface moisture from dew or rain it is theoretically and practically a "wet" substance, and it acquires the temperature of the wet bulb thermometer. From the moment the surface of the leaf is dried and until the leaf reaches a certain degree of dryness, the evaporation of moisture will still proceed comparatively freely and the leaf may still be considered as physically "wet". Even during this latter period, it will keep a temperature practically equal to the wet bulb if the lofts and the fan capacities are suitably designed. During the third period, the leaf departs from this rule, and a certain resistance is created inside the leaf against evaporation, and its temperature increases above the wet bulb.

It has been pointed out previously that the evaporation of water into air is proportional to the drying potential. As the air proceeds through the lofts, its drying potential decreases, and consequently, if all other factors are constant, the rate of evaporation of water also decreases until the air finally becomes saturated, when no water will evaporate at all. When this occurs, if the leaf is still a "wet" body, the elastic force of vapour in the leaf and in the air will be approximately equal. However, the evaporation may also cease, because the elastic force of vapour in the leaf continuously decreases owing to increased dryness and so becomes equal to the elastic force of vapour in the air. This is what may happen during the later period of the wither; the evaporation from the leaf may cease although the surrounding atmosphere is not saturated and the wet and dry bulb thermometers show a temperature difference. In this phenomenon lies a solution to the problem of producing withered leaf with an even and constant moisture content.

I have shown previously that evaporation will cease when the elastic force of vapour in the leaf equals that in the air. If, therefore, during the latter part of the withering one could keep an elastic force in the incoming air exactly equal to that which exists in ideally withered leaf, one could blow that air continuously over that leaf without the leaf becoming any dryer. At present the withering process is mostly carried out with no automatic control, and a comparatively dry air, i.e. air with a high drying potential is used. When such air passes over leaf for a considerable time, the final dryness of the leaf may become 30 per cent. or less. If on the contrary, one utilised air with a low drying potential and with a certain elastic force of vapour, one could cause the wither to cease automatically at a certain dryness of the withered leaf.

The drying potential has also to be considered in conjunction with the time allowed for the wither; and when the rate and degree of wither are properly combined, the withering process would be fully rationalised.

A low drying potential affords another advantage in withering. It is known that different parts of the flush evaporate water more or less freely, mainly depending upon the surface exposed to the air by various parts. During a fierce drying action, the parts of the flush with big surfaces exposed will evaporate water more quickly and become drier than other parts. This must by all means be avoided, but it can only be done by arranging for a comparatively low rate of evaporation throughout the whole withering.

Another problem is the evenness of the wither in different parts of the loft. With a high drying potential in the air, the leaf nearest the air inlet will reach a very high degree of dryness while the leaf at the end of the loft or in the middle, if any reversible system is used, will become less dry. Even with a comparatively wet air in the loft, it is true that at the beginning of the wither there will still be a difference between the leaf near the entrance and the leaf at the exit, but this difference will disappear almost entirely, because when the leaf nearest the entrance has reached a certain dryness, this leaf will not evaporate any more water to speak of and the air will pass practically unaffected over it, ready to act upon a leaf with a higher degree of wetness. This evening out will not occur during the two first periods of the wither, but takes place during the last period when the leaf has become slightly hygroscopic.

Planters are always of the opinion that the natural wither is preferable to any artificial. In my opinion, this is solely due to two defects in artificial systems. The volume of air actually passing through the lofts is often too small, and the drying potential which, in consequence, has to be employed is far too big. There is no difficulty either in theory or practice in reproducing the conditions of the atmosphere which are known to produce a good natural wither, every day of the year. Furthermore, one can control the condition of the air in such a way that it suits leaves of various moisture content and so improve upon average natural conditions.

It is generally believed that a wither should take place at a low temperature, which does not necessarily mean a low dry bulb temperature, but a low wet bulb temperature. However, the difference between the two should be comparatively small. A good artificial withering system ought to provide for a low temperature of the leaf itself. The only cheap method of achieving this is to cool the air by humidification, and this is only possible when the air is dry. The maximum number of degrees which the air can be cooled in this way is the hygrometric difference. If for instance, the air has a hygrometric difference of 15°F. one may cool such air by humidification 10°F. and it will still have a hygrometric difference of 5°F. which is quite sufficient to complete any wither if only the amount of air passing through the loft is sufficient. This method of cooling can be utilised only during spells of dry weather. If one wants to cool the air also during wet periods, one has to use some kind of refrigeration. In Assam where the air occasionally reaches 100°F. and is almost saturated, one would like to cool such air to say 80°F. and still have a hygrometric difference of 5°F. To achieve such cooling however was a very expensive process so long as refrigerating machinery had to be used. Fortunately, nowadays one knows of processes for cooling air where no machinery is required and in which, peculiarly, heat is the only agent employed.

To sum up, the wither can be fully controlled by controlling the drying potential in such parts of a country where excessive temperatures do not occur. It is, however, not sufficient to keep the drying potential at a constant value during the whole time of the withering. On the contrary, it is necessary to vary the potential according to the requirements of the leaf, especially towards the end of the withering and then to use air with a potential which will give and maintain the final moisture content in the leaf desired. A controlled wither of this type consists of two different periods, a first period, during which the surface moisture of the leaf is taken off, when a comparatively high rate of evaporation is maintained, and a second period, the main purpose of which is to even out the wither throughout the loft and to reach the final constant moisture content.

The practical method by which this can be achieved is an automatic control of the drying potential of the air with a super-imposed time control, which control is actuated by the original wetness of the leaf that enters the withering loft. In order to show the accuracy with which the final moisture content of the leaf may be reached with this method, the following experiment has been carried out.

Leaves of originally different moisture content, viz. 80 per cent. and 76 per cent. respectively were placed beside each other on the same tat and withered during 24 hours with a fairly strong breeze of air passing over it with a controlled drying potential. The result after 24 hours was 60·0 and 60·7 per cent in the two different types of leaf. This example is not intended to show that this accuracy can be reached in a big loft; even if the leaf in the experiment had finished off with 61 and 59 per cent. the result would have been considered as satisfactory.

If a good artificial wither is to be attained, it is essential that a great amount of air is used. Unfortunately many firms selling fans, when stating their capacity give a capacity corresponding to free inlet and outlet, which capacity is of no interest to the man who is going to instal the fan in a factory where it is not going to have free inlet and outlet. In lofts there always exist a certain resistance against air movements, and the bigger this resistance, the smaller the volume a certain size of fan can push through. It is therefore essential when installing an artificial withering system to know what resistance in the lofts one has to deal with, and the fan capacity must be chosen accordingly. In this connection it may interest the reader to know that the decrease in air volume from a propeller fan by resistance is considerably more than the decrease when using an enclosed fan. The propeller fans common in tea factories at present are not capable of dealing with a higher pressure than $\frac{1}{4}$ in. water column without losing a considerable amount of their capacity. For artificial withering systems one therefore ought to use either enclosed fans or propeller fans of the high pressure type which at present can be made to deal with pressure up to 8 inches.

The path along which the air travels in a loft is also of importance and the shorter distance the air travels the more even will the wither be. If therefore the air was blown across the loft instead of along it, and in addition was reversed, a higher degree of evenness would result than normally occurs with any natural wither.

With these remarks on withering I will conclude this article and I only hope that it will be of some use to the tea industry. I have as much as possible omitted to deal with the matter in a purely theoretical way, and I have always tried to exemplify each theoretical statement with practical experience common to every planter.