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THE CONTROL OF THE TEMPERATURE IN WINE FERMENTATION.

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The Control of the Temperature in Wine Fermentation

By A. P. Hayne.

The Control of the Temperature. The fermentation of wine must, or the juice of the grape, results in the main in the splitting up of the sugar it contains into almost equal parts of alcohol and carbonic acid gas. While there are other products of fermentation, it is not essential for our immediate purpose to dwell on them in this connection. The transformation of sugar into carbonic acid gas and alcohol is a chemical action caused by minute plants or ferments called yeast. It is well known that *all chemica changes of this sort produce heat;* and thus it will be seen that the temperature of a fermenting mass of a sugar solution (grape juice), while it depends to a certain extent upon the outside temperature, is chiefly dependent upon the *amount of heat generated within the tank itself.* The amount of heat, then, that is produced in a fermenting-tank depends upon, first, the percent of sugar in the must and the quantity of must; second, the facilities offered by the tank and air for carrying off the heat generated by fermentation, or conductivity of the tank-walls, the amount of surface exposed to the air, the circulation of the must within the tank, etc.; third, the activity of the yeast cells, *i. e.* the rapidity of fermentation.

Percentage of Sugar. The amount of sugar in the must varies from year to year in the same place with the same varieties. In hot countries there is, other things being equal, more sugar in the must than in cold countries. Some varieties of grapes give more sugar than others; and as high alcoholic strength is, unfortunately, paid for as such by the merchant, grape growers are apt to select those varieties that produce the most sugar, and hence alcohol in the wine, regardless of true quality. While this may be proper enough in cold climates, it works great injury to the general reputation of the wines of warmer countries, for alcohol is not the only desideratum in wine. In hot climates there is almost always, with the excess of sugar, a correspondingly smaller amount of acid. It is, however, important to note that very high sugar contents of must and low acid generally go together, and that they both are, as a rule, undesirable.

Excess of Heat. The amount of heat generated within the fermenting tank is very great, being sufficient, theoretically, to raise above boiling point the whole of a must rich in sugar. Practically, however, the heat is generated gradually; and much of it is carried off by the gas generated as well as through the walls of the vat, and from the surface of the fermenting liquid; otherwise fermentation beyond a certain point would be impossible. This fact has taught wine-makers in warm countries the necessity of a free circulation of air in the fermenting-room, unless that air is hotter than the temperature of the fermenting mass. Hence the benefit of the practice of fermenting in small packages with thin walls: first, because of less actual amount or quantity of heat (calories) generated; and, second, because of the facility with which this heat can be carried off and thus the equilibrium between the temperature of the ferment ng mass and the outside air be maintained. This has led many winemakers to have their tanks made of small diameter, of great height, and f very thin *material of high conductivity, such as thin enameled iron.* Vhile this certainly enables the operator to completely control the temperture, it has proved far too expensive for general use. But unquestionably he growing custom of using very large tanks is essentially bad practice.

Activity of the Yeast. The third factor in the problem is the activity of he yeast-cell. There are many circumstances that modify this activity. irst it must be remembered that the yeasts are plants, and that, in a genral way, their growth (activity) is modified by the same conditions that ffect the higher plants growing in the fields. Extremes either of heat or old are unfavorable to their maximum development. Thus in cold limates the wine-maker keeps a fire constantly burning in the fermentingoom, while in hot countries all his energies are bent on reducing the emperature to that most favorable for proper fermentation.

It is also noted that the higher plants have different "*optimum*" teneratures; for there are tropical plants, plants of temperate regions, and lants that grow in the arctic regions. It is the same, within certain imits, with the yeast plants. This variation is, as yet, but little known, or it is within but a few years that serious attention has been given to his branch of science so magnificently set forth by Pasteur. Suffice it to ay that something has been done, and that the beer brewers have put hese principles in practice with eminent success. Now the yeast plant of he brewers splits up sugar into alcohol and carbonic acid gas, just as the vine yeasts do, and is influenced by exactly the same conditions.

In the case of the seeds of the higher plants of all kinds, activity does not begin until the proper temperature has been reached. Should the emperature in spring rise slowly, the growth of all plant life is correpondingly slow; but so surely as a sudden great rise in temperature takes lace, plant life will be intensified by it until, when excessive temperatures re attained, it is either paralyzed temporarily or the plant may die.

Similarly, if the grapes arrive at the fermenting tank much heated, then we may look for a sudden violent development of yeast-plants or fermenation. *This is unfavorable for several reasons:* first, because the *heat is generated so rapidly* that a due amount can not be carried off in time by conduction, and high temperature is reached very quickly, whereby the yeast may be paralyzed or killed. But more than this; within certain limits each degree of sugar in the must means a corresponding amount of heat generated in the tank. Now if fermentation starts in at a low temperature, say 56 degrees F., the generation of heat will be slow at first, and the rate of fermentation will be correspondingly slow, and *apparently* less heat will be generated than if started at a higher temperature; because much is lost by conduction, although the *amount* is actually the same. The starting point was so low that the heat that was not carried off by conduction is not sufficient, when added to the initial temperature, to carry it to the killing point. Let the initial point be 75 degrees F., as is frequently the case, then the extra heat added by the greater rapidity of fermentation will carry the temperature, without doubt, to the death limit. Hence the many efforts made to get the grapes into the tank in a cool state. Wherever this can be done, the fermentation usually goes through well; but practically this is possible only on a small scale. Hence in a warm climate like that of California the initial temperature of the must is always over 60 degrees F., and in some cases over 76 degrees F. The danger arising from over-heating is, therefore, naturally to be expected. Actually, at all the wineries of this State, over-heating does occur almost continually, and great financial losses result therefrom.

Nourishment. But aside from the general climatic conditions, all plants are profoundly modified in their growth by the nourishment they receive from the soil in which they grow. Aside from the sugar required to nourish the yeast plant, one of the most important factors in the problem of its growth is the acid. There are other factors, but these are not essential in this connection. Now just as there are plants that will grow in alkali soil, and others that will not: so there are yeast plants that will thrive in a non-acid medium, and others that will not.

Diseases of Wine. This brings us to the plants that cause the *diseases* of wine; for it should be understood once for all, that a "spoilt" wine is spoiled not spontaneously, but by the growing in it of some minute plant which uses the substances of the wine to nourish itself, and to produce both its natural products, most of which are foreign to normal wine, and unpalatable besides. Thus the bacteria of putrifaction destroy otherwise edible meat and render it unfit for human consumption. In the same manner all diseased or "spoilt" wines have been rendered so by some plant of a lower order than the yeast-plant that gave it its quality.

Importance of Proper Temperature. Returning to the question of temperature, it has been established beyond the possibility of rational dispute that, in the majority of cases, those temperatures most favorable to the wine-yeast plant are unfavorable for the development and growth of disease-plants or bacteria, and *vice versa.*

In a general way we may say that the wine-yeast is a plant of the temperate zone, while the disease bacilli are plants of the tropics; the one requiring moderate heat for its normal growth and the other requiring a much higher temperature in order to grow and act at all. *This explains the practice of keeping wine in cool cellars.* This is a very *important point. High temperatures are very unfavorable for normal* wine-yeast, and very *favorable* to the bacteria which cause wines to spoil. After the limit of temperature favorable to the yeast-plant has been passed, the quality of the wine deteriorates with great rapidity; not necessarily because the wine-yeast is actually killed, nor that its action has ceased altogether; but that its activity has been checked, and that the harmful bacteria have begun their work; producing, not alcohol, carbonic acid gas, glycerine, etc., but their own characteristic products such as mannite, acetic, lactic, and butyric acids, etc., etc.

Paralysis and Death of Yeast-plants. The degree of paralysis of the yeast-plant depends upon the temperature and composition of the must. The absolute point of temperature at which paralysis or death will overtake the yeast-plant cannot be fixed absolutely, as it depends upon the variety of ferment or yeast-plant, as well as upon the conditions in which it works best. For normal musts with a normal yeast, the death point is generally from 98 to 100 degrees (F). Some varieties of yeast (and these are few) will stand more heat, most of them suffering greatly before this point is reached; the must also should be of a composition naturally favorable to them. Before this point is reached the bacteria begin to develop, while the wine-yeast stops growth and the wine, if not spoiled, is rendered of less value than it would have been, had the temperature remained lower.

Effect on Bouquet and Aroma. It should be noted in this connection that, with certain reservations, the general rule is that the lower the temperature of fermentation the better the aroma and bouquet of the wine. In other words, the proper regulation of the temperature of the must during the first or tumultuous fermentation means the production of a wine richer in alcohol, of better keeping qualities, and better quality throughout.

Use of Antiseptics and Antiferments. With this review of the general principles governing fermentation, we come to the practical lessons deducible therefrom. We have had occasion to note the heavy annual loss to wine-makers from "stuck tanks," resulting either in the total destruction of the wine, or the partial loss of its market value. We have also had occasion to listen to the criticisms of the purchasers of California wine, both abroad and in this country; and in by far the greater number of cases the fault found was not so much with the quality, (for well-made California wine compares favorably, grade for grade, with any in the world) but in the *unsoundness, i. e.* the tendency to spoil on the hands of the purchaser before reaching the consumer. This has led to the use of antiseptics, "anti-ferments," that is poisons which kill outright or paralyze, not only the wine-yeast but all bacteria that might intervene, and in some cases the consumer as well. The making of wine at high temperatures is simply inviting the use of antiseptics; for, as a matter of fact, *unsound wine can only be marketed by the use of some powerful agent, to keep the bacteria in check.* Few wine-makers realize the great harm done to the reputation of Californian wines by a few unscrupulous or ignorant dealers who systematically buy up unsound wines, "doctor" them, and ship them abroad. The sooner the use of antiseptics of any kind (except pure wine alcohol) is stopped, the better it will be for all concerned in viticulture. It is to be regretted that there is no law enforced that punishes those who use dangerous drugs in wine.

Stuck Tanks. A "stuck tank" is a very common occurrence at most all wineries in California, as well as in all countries having similar climates. It means that the yeast germs that convert the juice of the grape into wine have suddenly ceased their normal action, and fermentation proper has ceased, while bacterian activity has started up; resulting either in the total or partial loss of the wine. One wine-maker of this State told us that his loss from stuck tanks amounted in a single season to $10,000; and there are but few who do not suffer to a certain extent from this trouble.

As has been shown, the commonest cause of stuck tanks is too high temperature. The trouble is not by any means confined to California; but is the curse of all wine-making countries in the warmer parts of the world, viz. all Southern Europe, North and South Africa, Australia, etc. The wine-maker of these countries has been found to be less self-complacent than his California brother, and has made serious efforts to control the temperature of fermentation.

Methods of reducing Temperature. By some wine-makers the amount of sugar was reduced by the *addition of water*. This, in many cases proved of great service, but in others it was not so; for the water also reduces the acid and the body of the wine, and unless there be sufficient acid, normal fermentation does not take place, save under exceptional circumstances. Others tried to reduce the temperature of the wine by the *addition of ice* to the fermenting tank. This had not only the same effect as the addition of water but proved utterly impracticable in the case of red wine and is not economical. Some tried the use of *metal spiral coils* plunged in the fermenting tank through which cold water was passed. This proved successful in the case of wine fermenting without skins or stems (white wine); but was impracticable in all cases where the skins and stems were left in the tank, owing to the impossibility of sufficiently mixing the hot and cold parts of the fermenting mass. Others tried *metal tanks*, but this was found to be too expensive.

Again, some tried pumping the wine from the bottom of the tank over into the top and allowing it to spread out in a spray. This accomplished two results: it *cooled* the wine slightly (but very slightly) and especially did it *revive* the partially paralyzed yeast cells by giving them a fresh supply of free oxygen. The fatal defect of this practice was found to be that too great oxidation and evaporation of the alcohol, which took place at high temperatures, the wine becoming too highly charged with acetic acid (vinegar-sour). Nevertheless, this pumping over of the wine of stuck tanks, or tanks that threaten to stick, is now widely practiced all the world over, and in the case of a sudden stopping of fermentation it is necessarily done to supplement the addition of fresh must in active fermentation used to finish the conversion of the sugar into alcohol and carbonic acid gas.

Experiments at the University. Convinced of the necessity of controlling the temperature of the fermentation of wines in this State, (just as the brewers do that of their fermenting wort to a fraction of a degree, always getting a product the value of which is known beforehand), the Viticultural Staff of the College of Agriculture set about to devise some practical method for attaining this end. It was only after having completed the experiments with the apparatus herewith described, that we received detailed data of the European experiments with the refrigeration of wine. We give below a complete description, first, of the French apparatus; second, of the one first devised at the Experiment Station; and, third, of the one modified as found advisable after thorough trial.

Apparatus used in other Countries. Figure 1 represents one of the forms of the apparatus now used throughout Northern Africa and Southern France. As will be seen, it consists essentially of two columns, each made up of nineteen thin, well-tinned, horizontal copper tubes. These tubes are 13¼ feet long by 1½ inches in diameter. The total length of the tubes through which the wine passes is thus nearly 500 feet. These tubes are fitted into solid bronze castings closed by means of a bronze plate over a rubber washer, with thumb screws. The two columns are connected by a tube (3 fig. 1) running diagonally from the top of one column to the bottom of the other, so that the hot wine entering at the lower end (7 fig. 1) of the first column, and after passing upwards and completing the circuit in this column, passes to the bottom of the second column, from

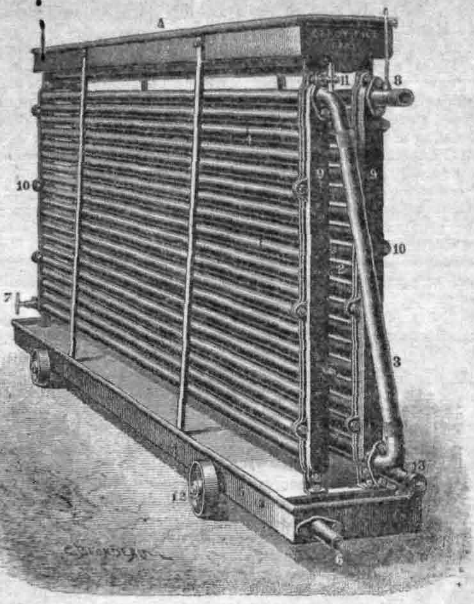


Fig. 1.

hich again it escapes at the top. Above the two columns of tubes is a large etal water-box, having two rows of holes in the bottom corresponding the two columns, from which cold water is allowed to drip as the warm ine is pumped through the tubes. Under the apparatus is a metal box hich catches the drip of warmed water. Each column of tubes has a op-cock (13) which allows rapid emptying of the wine when pumping stopped. The apparatus is, as before said, now actually in use in other ountries and we are indebted to the excellent report of Messrs. Müntz and ousseaux in *La Revue de Viticulture* for the results of their exhaustive xperiments conducted in France during the past season, 1896, as well as uring the season of 1895.

The first defects that strike one in this apparatus is the unwieldiness nd expense, as well as the large amount of labor required to force a one-nd-a-half inch stream of wine through such a length of tubing at a work-g rate; then the amount of water used in cooling the wine must be very rge, unless the temperature of this water be considerably below that of the wine. As in the case of the use of ice, it will do well when all conditions are most favorable.

In a recent article, giving a resumé of the two seasons' experiments, Messrs. Müntz and Rousseaux tell us that to work the apparatus, a gang of four men, working in relays, is required to pump forty hectoliters or 1060 gallons per hour. With a motor engine, double this amount could be pumped through, but the *quantity of water* needed in this case for the proper cooling of the wine is enormous, amounting to from one to one-and-one-half times the amount of wine passed through ; or far more cold water than is generally to be had at the average California winery.

The reduction of temperature was in some cases very great, but depended altogether upon the rate of pumping, the amount of water dripping over the tubes, and the initial temperature of this water. There was an average reduction, however, of from 10 to 12 degrees F., but in some cases a maximum of as much as 20 degrees when slow pumping was practiced. The cost of cooling the wine was, on an average, one-thirteenth of one cent per gallon.

From the careful tests made by these eminent scientists, the remarkable benefits of cooling the fermenting mass was strikingly shown. In all cases a certain lot of the same must was fermented in the usual way as a check to the experiment, and in every case the cooled wine was sounder and of far better quality. Microscopic examination showed that the uncooled wine was teeming with harmful bacteria, while the amount of unfermented sugar remaining was very considerably more than in the case where the wine had been cooled. The University experiments showed this as strikingly as did those of Müntz and Rousseaux.

We give below a table taken from *La Revue de Viticulture* in which some of these results are set forth. Unfortunately the recent disastrous fire at the Agricultural Building at the University destroyed all the notes taken at each tank cooled, so that we can but give the general results. These results were, however, *looked over but a few days before the fire* and being compared with those made in France by Müntz with his apparatus were found to be essentially in accord, as appears from the data given below. We give below the exact figures obtained by these observers. This shows the matter to be not of something "*theoretical*" and untried, but something that has been *tried by several, and proved to be a practical success.*

The experiments were made in the Roussillon district of France, near the Eastern Pyrenees, during the season of 1896, with Carignane grapes.

	Maximum temperature of the must *during fermentation*	Alcohol per cent.	Unfermented Sugar.
Cooled Wine	96 (F.)	11.00	
" "	96.8	11.45	.59
" "	99.5	11.50	.65
Uncooled Wine	102.2	10.20	2.60
" "	104.0	10.10	3.30

It will be recollected that experiments made by Prof. Hilgard at the University, in 1887, gave almost precisely similar results as to alcohol percentage when hot and cool fermentations were compared. (See Report of the College of Agriculture on Methods of Fermentation of 1886-87, p. 28.)

The effects of high temperature on the composition of the wine may be further illustrated by some other analytical results from the French experimenters, Müntz and Rousseaux, who found in 1895 that a wine which had attained a maximum temperature of 98.5 degrees F., during fermentation showed on analysis .066 percent of ammonia, while another wine made from the same lot of grapes, which attained a maximum of 104 degrees, showed .60 percent. Similar results were obtained in 1896, when maxima temperatures of 94 degrees and 104 degrees gave .03 percent and .22 percent of ammonia respectively. It is clear, therefore, that serious chemical differences and defects are produced in the wine by high temperature fermentations apart from the swarms of disease bacteria which are always present in such wine. Of the wines made by Müntz and Rousseaux in their 1896 experiments, those that were not cooled threaten to spoil already; while those that were cooled are in perfect condition.

EXPERIMENTS MADE BY THE UNIVERSITY AT NATOMA, SACRAMENTO COUNTY, AND AT EVERGREEN, SANTA CLARA COUNTY.

Apparatus used. The results of Müntz and Rousseaux were amply confirmed by the investigations undertaken by the Viticultural Staff during the season of 1896 at the Natoma Vineyard in Sacramento County, and at Mr. Wehner's at Evergreen, near San Jose. The apparatus used by us differed greatly from that used by Müntz and Rousseaux, and the many others abroad who practiced refrigeration during fermentation at the same time.

Not being able to avail ourselves of the detail of the numerous experiments undertaken along the same lines abroad during the past few years, we had to construct our apparatus independently upon what we considered the most promising lines; fortunately, as it turned out, committing few mistakes and obtaining results that show our system to be far superior to any thus far proposed for California conditions. However, experience has shown us the desirability of certain changes and modifications as hereinafter shown, especially as mechanical power for pumping and crushing is available at nearly all wineries of this State.

The apparatus shown in figure 2 is the one designed and used by us in the experiments. It will be observed that insofar as the pumping of the heated wine through tinned copper tubes goes, the principles are identical with those of the French apparatus. The method of pumping is the same as is in practice at wineries for drawing off the newly fermented wine from the fermenting tank. The wine is drawn off from the bottom of the tank and strained through a sieve into a tub, from which it is pumped through the apparatus into the top of the tank again. In other respects there are important differences; thus, instead of two columns consisting of 498 lineal feet of tubing, our apparatus consisted of a single column of only 42 feet of tubing. The tinned copper tubing instead of being *perfectly round is very much flattened*, thereby giving greater cooling surface to the same volume of wine, a material improvement on the French

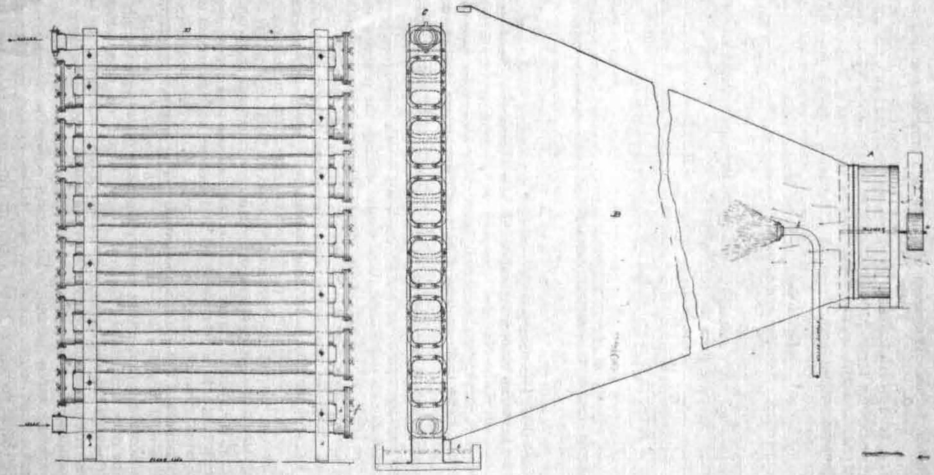


Fig. 2.

system of round tubes. It consists of 14 pieces 3 feet long and 4 inches broad, by 1½ inches deep. These tubes are fitted into bronze castings which are closed by plates fitting over rubber washers, and fastened by thumb-screws, thus allowing the tubes to be readily cleaned in cases of obstructions that might occur in the pumping through of the muddy, partly fermented must.

METHODS OF COOLING.

Water-box. In our first experiments the whole apparatus, that is to say the column of tubes, was fitted into a box, tin-lined and filled with water. A constant supply of fresh water entered the box at the bottom, escaping from the top, while the wine entered the top of the apparatus and escaped at the bottom, in order that the *coldest wine* should come in contact with the *coldest water*, and *vice versa*. It is well known that this arrangement will give the greatest amount of cooling effect.

It was found that by the use of a very large quantity of water the wine could be sufficiently cooled, but the excessive amount of water thus required caused us to abandon this system. In special cases, where an unlimited water supply is to be had without too great expense, this system should be adopted, for though the cost of water-box and installation will about offset the cost of the blower and canvas sleeve, hereinafter described, it has the advantage of doing away with the necessity of the command of power. In case this system is adopted, it is well to use a greater length of tubing than would be required where the spray and the air current are used. Roughly speaking, the amount of water used in this case should be from 1½ to 2½ times the volume of wine pumped through the apparatus.

Drip, Spray and Blast. Instead of depending upon the simple dripping of the water over the tubes to effect the reduction of temperature of the warm wine, a great saving of tubing, as well as labor in pumping, was found to be effected by the use of a fine spray of water carried by a strong blast of air, thus combining the effects of cold water and evaporation. The quick evaporation brought about by the dry air prevailing at our vintage season, when mingled with a fine spray, produces a cooling effect far in excess of what could be obtained from the ordinary water at the wineries alone. This is important, for at many of the wineries the water available is very warm and the difference between the temperature of the water and the wine to be cooled is so slight that it would be impossible to effect a proper amount of cooling, unless enormous volumes of water were used.

The proper proportions between the air blast and the amount of water sprayed is of the utmost importance. It is readily understood that a weak blast with a large amount of coarsely-sprayed water would leave the temperature of the water almost unchanged when it reaches the cooler, and would, therefore, amount to little more than the dripping practiced in the French apparatus; while if the blast be in excess and the water deficient, the amount of water carried may not be sufficient to utilize the evaporative power of the blast, nor to thoroughly wet the tubes. Again, to insure the maximum cooling from evaporation, the spray should be so fine that within the short distance from the nozzle to the tubes the air may become fully saturated, and both cooled to the fullest extent. Of course, the heavier the blast, the more water spray can be carried and cooled by it.

To produce the requisite fineness of spray, an adequate water pressure is necessary.

Another factor of the utmost importance is the dryness, or what is technically called the "relative humidity" of the air used. During the vintage season this is frequently as low as 33% *outside of the winery*, and the intense evaporating effect producible under such conditions should be utilized by connecting the intake with the outer air. This, of course, can be done either by a canvas tube stretched by hoops, or by a board flume.

When, as may happen near the coast, the moist condition of the air is unfavorable to strong evaporation, the water temperature, on the contrary, is frequently itself so low that an energetic spray without a blast may suffice to do the necessary amount of cooling.

It will be noted, therefore, that the best conditions for cooling will vary, not only in different localities, but on different days, and according to the prevailing wind; so that it is impossible to prescribe the exact strength of blast or quantity of spray that should be used. But a few experiments will determine the best practice in any given locality.

In our experiments the blast of air was generated by means of an 18-inch "double" (8-wing) blower, or "exhaust-fan" reversed. The water escaped from a battery of three Vermorel nozzles placed immediately in front of the blower.

A conical canvas sleeve attached to the outlet of the blower and five and one-half feet away to the circumference of the cooler-frame prevents the loss of blast and spray.

The "double" 18-inch blower requires under ordinary circumstances less than one-half horse-power to run it at a rate of 1000 revolutions per minute, and thus, with a free supply, will pass 3000 cubic feet per minute through it. The 24-inch "double" blower requires about the same horse-power to run it, but requires only 900 revolutions per minute to send through 5000 cubic feet in the same time. It should be remembered that the best efficiency of every blower is limited to a definite velocity of revolution. The figures above given refer to the most favorable velocities for the sizes mentioned. The one costs $40.00 (less discount) while the latter costs $50.00. In order that the apparatus may be available at small-scale wineries, where no steam is used, it may be well to state that a small gas engine, run with common "distillate" and giving two and one-half horse-power, can be had for $187 (less discount). The cost of running such a motor is one cent per horse-power per hour; a trifling expense, especially as the motor, once started, will run itself, so that one man can attend to the pumping of the wine and the running of the engine at the same time. Indeed, with a little fitting, such an engine could be made to do all the pumping in the cellar, and there are no laborers who will do one horse-power of work for a cent an hour.

While the French apparatus was movable, ours was of necessity fixed, but with one man at the pump at Mr. Wehner's place it was found that he could pump from the most distant tank at the rate of 1000 gallons per hour, in some cases as much as 1400 gallons. At this rate a reduction of temperature of from 10 to 13 degrees was obtained in the wine. The temperature was taken at the point where the wine left the tank and again where it re-entered the tank after having passed through the cooler.

Precautions. We found that the much-feared *deposit of cream of tartar* on the inside of the tubes was very slight indeed. It would seem that while warm wine on cooling will deposit cream of tartar on the lining of the vessel, wine constantly in motion (as when being pumped) will not deposit much. Even after long use it was found that the thin coating of cream of tartar on the inside of the tubes could be removed by pumping the apparatus full of water and leaving it over night after a few barrels had been pumped through. The apparatus should be flushed out at least once in twenty-four hours, for the deposit of cream of tartar, be it ever so slight, interferes greatly with the conduction of heat, and anything that has this effect must be carefully avoided. Even the surface of the tubes should be polished once a day with ashes or lye, for there forms on the surface, after a day's use, a "greasy" film, due to the lubricant necessarily used in the blower, which not only interferes with the conduction of heat, but causes the water to run in streaks over the surface instead of spreading over it, much cooling surface being thus lost.

The seeds and skins should be kept out as well as possible from the pump and consequently from the apparatus. By exercising due precaution in this regard, we did not have to clean the apparatus from this cause once during the entire trial.

Control of Temperature. We found, as did Müntz and Rousseaux, that when the wine passed 100 degrees, cooling was useless, for the ferments or yeasts were too badly injured to be revived. Thus a tank at Natoma (where the conditions were unfavorable on account of hot weather) was fermented with some Algerian yeast, and was allowed to go as high as 104 degrees. The tank "stuck" before fermentation was finished and it could not be revived by cooling.

Müntz and Rousseaux state, that if a tank is cooled before the temperature reaches the danger limit, there need be no fear that a subsequent rise to this limit will take place. We found at Mr. Wehner's that under the conditions existing, when the temperature in the tank reached 88 degrees, if we pumped about one-half or two-thirds of the contents of the tank through the cooler, nothing disastrous ever happened, although the fermentation kept right on and the rise in temperature continued, yet it seemed that a sufficient amount of heat (calories) had been removed from the fermenting mass to enable it to complete the fermentation without reaching the danger point. This favorable result, however, must largely depend upon special conditions, and should not be relied upon so as to relax vigilance.

Considering the fact that low temperature fermentation gives a wine of a different composition from that fermented at high temperature, and leaving for the moment the killing of the yeast out of the question, it is evident that it would pay to keep the temperature constantly below the danger limit on account of the superior quality of the resulting wine.

It might not pay in ordinary cases to go to this expense for quality alone, yet if extra fine wine is to be made, extra care must be bestowed upon it.

Aeration of the Wine. It was deemed advisable to aerate the wine whenever it was pumped over. In order to accomplish this, and at the same time to prevent the cooled wine from forming a channel in the cap and passing at once to the bottom and thus leaving the warmer wine at the top, we caused the wine to escape from the end of the hose in a fanlike jet, the direction of which was from time to time so changed as to reach all parts of the cap during the cooling. In this way the cap was very greatly cooled, which is important as it is the hottest part of the fermenting mass in a tank.

In all cases where the cooling took place at or about 88 degrees, the tank "went dry" perfectly well, and the resulting wine was drier and far clearer than in case of the wine not cooled and aerated. This was especially noticeable in cases where pure cultures of yeast were used, especially some of the foreign varieties.

In some cases we tried the use of an extra empty tank into which the cooled wine from the first tank pumped was put, and the cooled wine from subsequent tanks was pumped into the first tank. At the end of a certain time the wine first cooled was pumped into the last tank. In this way one avoids cooling the same wine or part of it twice, but an extra pumping is thus necessitated. The avoidance of cooling wine that has just been cooled and pumped back to the top of the tank is certainly an important problem that must be solved by each wine-maker according to circumstances. We would suggest that a storage tank at a greater elevation than the fermenting tank be used as a common receptacle for all cooled wine. As soon as a sufficient amount of wine in any given tank has been cooled, it can be returned by gravity, and thus all danger of wasting energy by pumping the same wine twice through the cooler can be avoided. It is true that there will be an extra amount of labor required to force the cooled wine to a greater level than that of the fermenting tank.

Faults of the Apparatus. It was found that with our first apparatus we had made the mistake of placing the tubes too far apart (2½ inches), losing thereby a very considerable amount of air and spray. This we had to remedy for the time by filling up the space with two-inch slats; but this, of course, caused a great waste of cooling effect. We therefore, in our modified apparatus, recommend that the tubes be placed an inch apart, which is the practical limit for the successful soldering of the tubes into the castings, more especially when the tubes are of such greater width as we now find desirable. The horizontal position, moreover, will always prove a source of waste on account of allowing too ready a passage for the current of air and spray. It was also found that for large scale operations the cooling capacity of the apparatus was not adequate.

THE NEW APPARATUS.

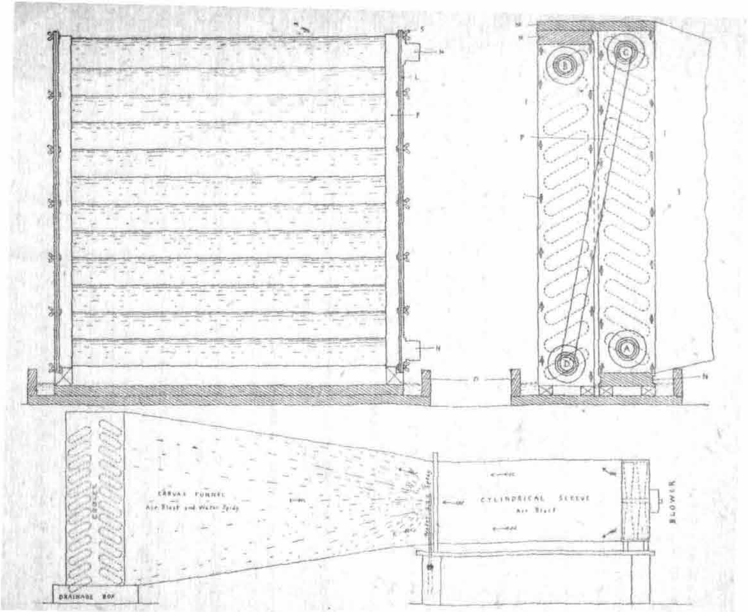
In the construction of the new apparatus the need of greater capacity was first considered. The lengthening of the tubes as in the French model renders it very cumbersome, and it therefore seemed preferable to retain the same length of tubes, but to give them an increased cooling surface by enlarging their dimensions to 5½ x 1½ inches, and to use two batteries or columns placed one behind the other. This arrangement would serve in any case to utilize better the cooling current which must always waste through a single system of tubes however placed. Moreover, the increased cooling surface obtained by widening the tubes does not involve an increase of friction, as would a lengthening of tubes, to attain the same purpose.

Another modification deemed wise is to have the extremities of the tubes closed by a single bronze casting instead of separate castings for each pair of tubes. These castings are fastened by thumb-screws over rubber washers, as in the case of the first machine. The advantages are that it not only requires fewer thumb-screws (and hence allows greater rapidity in cleaning), but also that the solidity of the whole apparatus is greatly enhanced, and the necessity for an extra frame is done away with. We found that with the great number of small castings it was difficult to keep any frame from "giving" a little. (See Fig. 3.)

Relative Position of the Sets of Tubes. In order to determine as nearly as possible the various conditions needful to secure the best results, two sets of tubes of twelve each were placed in a convenient frame, and so suspended on chains that both their distance and their relative positions could be readily changed at will. While this would not enable us to determine exactly all the best conditions in the completed arrangement, it would at least enable us to avoid such mistakes as rendered the first apparatus to some extent unsatisfactory.

It soon became apparent that so long as the tubes in the two sets were placed parallel to each other, whether horizontally, or inclined upwards or downwards, even when arranged as closely as practically possible, and so as to break joint, there was a great waste of spray, and therefore of cooling power, in the rear of the second column. The obvious remedy was to place them at an angle to each other, so that the current should be considerably checked and its direction completely changed before being allowed to emerge at the rear end of the apparatus. It remained to be determined whether the relative inclinations should be in the form of a V or of an A, and what the angle of the inclination should be. It was evidently not desirable to make this angle steeper than necessary to accomplish the purpose.

Points observed. In making the experiments the points observed were: First, the absence of any considerable waste of spray beyond the second column; second, the approximate equality of the drip of water from both sets; third, the diminution of temperature obtainable with varying strength of spray and blast. We could thus as nearly as possible estimate the results likely to be obtained by the apparatus when completed. In all experiments so far made the two sets were placed as near together as practically possible. As to the first point it was found that the least waste of spray occurred when the tubes were placed one inch apart in the inverted V (A) position, and that for this purpose an angle of 30 degrees was sufficient.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CANVAS FUNNEL
Air Blast and Water Spray
COOLER
DRAINAGE BOX
Water [illegible] Spray
CYLINDRICAL SLEEVE
Air Blast
BLOWER

Second, it was further found that under these conditions the drip from the two sets of tubes was most nearly equalized, and that their entire surfaces remained well wetted.

As regards the third point, it was found that in the space between the two sets the temperature was mainly governed by the strength of the blast and the amount and kind of spray used. In this respect our preliminary experiments could give only comparative values, since the saturation of the air at Berkeley at the time was between 75 and 80 percent, and the air temperature varying but slightly above and below 60 degrees F.

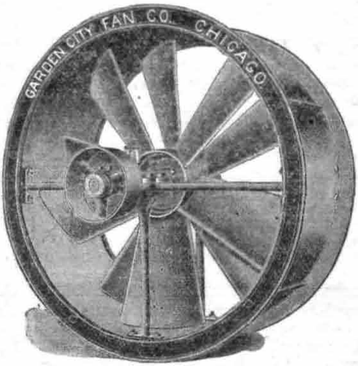

Fig. 4. Blower.

Air Blast and Spray. No mechanical power being available at the time at Berkeley, we had to restrict ourselves in the use of the blower to such a velocity as could be obtained by the power of two men, which was between 700 and 750 revolutions per minute, obtaining probably about ⅔ to ¾ of the effect of the blower, or about 2000 or 2500 cubic feet per minute.

It was quickly noted that as transmitted through the pyramidal canvas sleeve directly, the distribution of the wind over the surface of the tubes was very unequal, being very strong at the circumference and almost null in the middle, on account of the centrifugal action of the blower. This inequality was effectually done away with by the interposition between the blower and the pyramidal sleeve of a cylindrical sleeve 3½ feet long.

As regards the spray, a comparison of the reduction of temperatures obtained with the rather coarse spray heretofore employed, with that

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