

Incubation Method of Ripening Dates

Assisting Nature by Laboratory Methods

By Silas P. Markham

THE illustration presented on this page shows a fruiting date palm in the Salt River Valley, Arizona, which will ripen about 200 pounds of dates, while the photographs on the next page show the experimental apparatus for ripening dates by incubation and a sample of ripened dates packed for shipment. The writer is indebted to George F. Freeman, plant breeder of the experimental station at Tuscon, Arizona, of the University of Arizona, for the accompanying photographs and data.

He states that under the stimulus of this new process of ripening, many of the farmers of Southern Arizona are planting considerable areas to the date palm.

About a decade ago the United States Department of Agriculture sent a large consignment of the choicest of varieties of dates to Arizona, where they were planted and subsequently cared for at Tempe by the Arizona Agricultural Experimental Station. Many of the 200 varieties of dates there growing have ripened and are of varying degrees of promise commercially.

The most valuable variety of all, however, the famous Deglet Noor, which in the Arabian language means "the date of light," has never yet ripened satisfactorily in this climate, because the summers, though hot, are not long enough for the ripening process to become complete. The science and art of ripening the fruits has, therefore, been a subject of study by different members of the staff of the Arizona Experimental Station for years past.

Dr. A. E. Vinson found that the ripening process was due to the action of certain ferments called enzymes which, while the fruit is still unripe, are locked up in the cell contents of the growing dates. When the cells mature naturally, however, or are killed by heat, enzymes are released and become active, forming those substances which contribute to the flavor, aroma, and appearance of ripe dates.

Hot water, vinegar, gasoline and a score or more of other substances have been found to ripen dates artificially. Of these substances, vinegar or acetic acid was found best suited for practical work and by its proper use perfect commercial products were produced from many varieties.

Nature, however, often prefers the simplest means to accomplish her most perfect results, and it remained for Prof. G. F. Freeman, by exposing the partly ripened Deglet Noor dates from the orchard to just the right degree of heat and moisture in an incubator, to turn out dates that rival those sold on the Paris market from the African Sahara.

In this process the dates are picked when they show the first signs of natural ripening. After being washed they are placed in an oven where they are kept in a moist atmosphere at a temperature between 45 and 50 deg. Cent. for about three days. By this time they have become fully ripened, are moist, partially shrunk and very sweet. The same process is used in treating dates which have been allowed to remain too long on the palm, becoming dry and withered, except that they are soaked in water for six hours before going to the oven. When ripe the dates are packed in attractive little boxes, lined with wax paper having a lace border. The whole package is then wrapped in white moiré paper and tied with a ribbon after the fashion of candy boxes. These packages, whether open or closed, make an attractive exhibit and serve as an appropriate covering for the luscious fruit which they contain and on the whole make a product which is appreciated and readily accepted by the trade at prices which will yield 30 to 50 cents a pound for the dates.

Trial shipments have shown that dates ripened and packed as above described will reach the following widely scattered points in first-class condition: Seattle, Wash., Fargo, N. Da., Chicago, Ill., New York, N. Y., Washington, D. C., and Paris, France. All of the recipients of these packages were highly pleased and many expressed the opinion that the quality exceeded that of the best imported product with which they were acquainted. There is no doubt that dates artificially ripened and packed in Arizona will have a commercial range including the whole of North America.

Aside from the above noted trial shipment, the bulk of the crop has been sold on a single limited market, for the purpose of learning whether the initial ready sales were due to the novelty of the product and whether these dates are of such quality as would produce a steady and consistent trade in one locality.

Results so far have been gratifying and when considered in connection with the wide range of market

which the shipping qualities of these dates make possible, they indicate that there is little danger of overproduction in the limited area of Southern Arizona and California in which this fruit may be grown.

Of course, only the finest dates go into the confectionary boxes. Those which are a little less desirable are pressed into bricks and wrapped in stout tissue paper. Experimental sales show that the trade will take these block dates at 25 cents a pound in preference to the imported bulk date at 20 cents. Moreover, clerks in grocery stores where both kinds are sold will push the block dates rather than the imported bulk dates for the reason that sales can be made without soiling the hands.

Another reason for the better sale of the pressed dates in small, neat packages is that in addition to the fact of a more sanitary packing and handling than can be claimed for the imported product, their cleanly appearance of itself is not without weight in the mind of the customer.

On the strength of the evidences above outlined it



This Palm Will Ripen About 200 Pounds of Dates.

may be stated that even the choicest of the old world dates may be grown and satisfactorily ripened in Arizona.

Because of the fact that date palms thrive on alkali land, incapable of producing other crops, Prof. Freeman foresees a great future for the industry now that a method of ripening the fruit inexpensively has been found. It has been proved, he states, by the date orchard at the experiment farm near Tempe that the Deglet Noor palm will produce 250 pounds of dates to the palm, with the palms planted 50 to the acre. This, with a yield of even 200 pounds to the palm, will make a yield per acre of 10,000 pounds.

He figures that as a commercial proposition, the grower will realize 10 cents per pound from the dates, and that the middleman, who ripens and packs them, will sell them for 20 cents a pound. At that rate the grower will make \$1,000 per acre, gross profit.

The process requires only that the partly ripe dates be placed in pans in a room or chamber which is kept at a temperature of from 105 to 115 deg. Fahr. for two or three days. Moisture in the atmosphere of this room aids the process and will cause even shriveled fruit to become plump and luscious. The process is inexpensive and perfectly practicable on a commercial scale.

In a recent paper on "Ripening Dates by Incubation," Mr. G. F. Freeman states that the method described of ripening dates artificially by means of heat and moisture is not entirely new. He says: "The Mexican date growers of Lower California cut the bunches of dates after the fruit has passed from the astringent to the sweet stage, but before it becomes soft. The harvested bunches are next put in piles, which, in the

open, are covered at night with palm leaves or otherwise to protect them from the dew which would possibly contribute to their decay. Being left in this situation for a varying period of several days, the berries are next picked from the bunches and spread out on mats in the hot sun, the riper being separated from the greener fruit, day by day. At night, during the process, the fruit is protected by covering or piling it, thus measurably maintaining its temperature and keeping it from damage by fog or dew. As the fruit matures it is packed for storage or shipment."

Prof. Freeman holds that the heat of the sun during the day and the sweating effects doubtless brought on by piling or covering at night, offer conditions and produce results more or less similar to the artificial ripening process which he has used. Vinson reports that a certain fruit dealer in Algiers, whose dates are considered superior, is said to have a secret process by which they are treated in order to soften the hard and imperfectly ripened individuals. Other fruit dealers of the same locality are quoted as suspecting that this process consists in steaming or soaking the fruit.

Dr. Vinson recognized the effect of heat and moisture in date ripening as early as 1907. Speaking of Deglet Noor dates, he says: "Under normal conditions, 20 to 25 per cent of invert sugar is formed, but under the conditions necessary for artificial ripening, 45 to 50 deg. Cent. for several days, a much larger proportion is inverted."

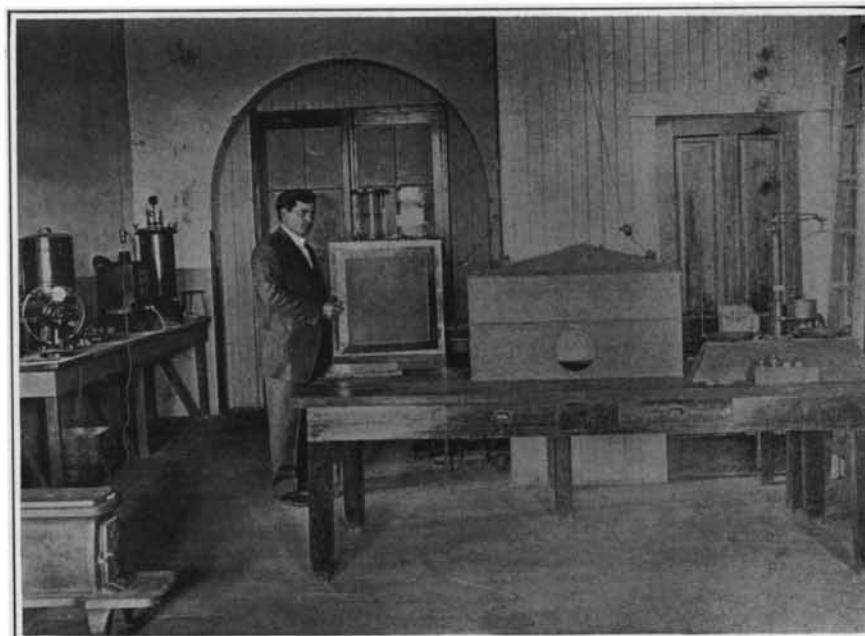
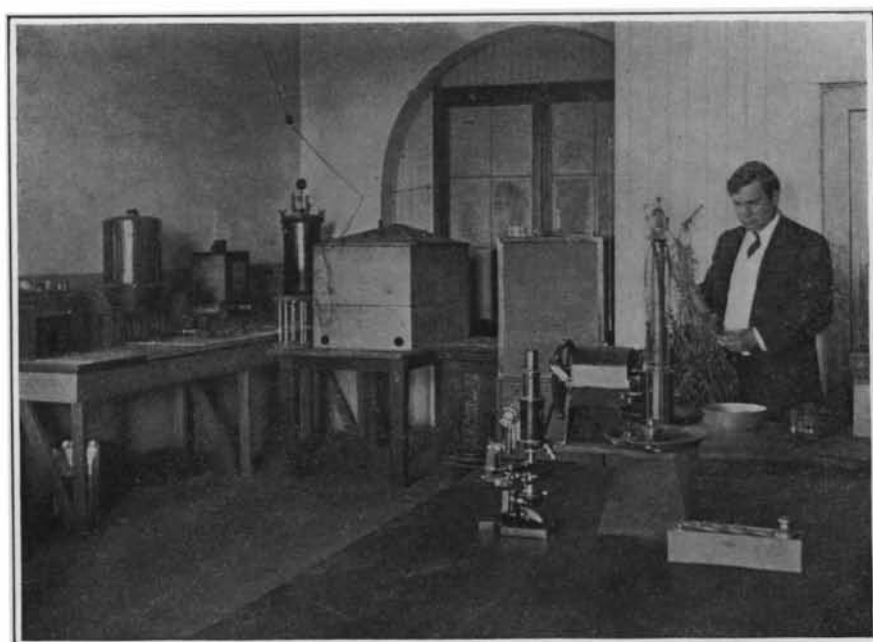
During the crop season of 1910, while Dr. Vinson was absent in France and Africa, Mr. Freeman became interested in the subject and developed the economic method of ripening dates by incubation described.

When the Deglet Noor is fully mature but not yet beginning to ripen the seed is hard, the skin is firm and the external layers of the flesh are opaque. At this time the color is light orange yellow with a strong blush of reddish orange on the sunny side. The first sign of ripening is shown by a slight translucence of the flesh just below the skin. As this increases and progresses toward the center of the date, the fruit begins to soften and wrinkle; and it loses volume with its loss of moisture in ripening. In the early, naturally ripened, invert sugar varieties, the skin is, for the most part, rather thick and brittle, and as the date shrinks it becomes separated from the flesh, dries out and cracks. These cracks offer access to predaceous insects and are ideal receptacles for catching and holding the moisture of occasional showers, thus hastening the souring and decay of the fruit.

The effects of temperature are very marked. The rapidity of ripening increases with a rise in temperature until a point is reached where both the protoplasm of the date and the enzyme which brings about ripening, are destroyed. This temperature is stated by Vinson to be about 75 deg. Cent. Mr. Freeman finds that even 65 deg. Cent. is too high to get a good quality of date. Ripening at a temperature of 45 to 48 deg. Cent. finishes the process in three or four days and seems to give the best fruit. Ripened at a lower temperature, a longer time is required and much fruit is liable to sour. At temperatures above 46 deg. Cent. there seems little danger of souring during the ripening process.

The temperature used also affects the color of the finished product. The higher the temperature, the darker the product. Naturally ripened Deglet Noors are of the translucent golden color. In artificial ripening this is changed to a translucent mahogany. This reaches its highest perfection in dates ripened at 44 to 45 deg. Cent. At about 50 deg. Cent. the dates become deep mahogany, lose their translucency and are much less attractive. These higher temperatures also cause the syrupy juice to exude and render the fruit sticky and disagreeable to handle.

Continued exposure to a lower temperature seems to have much the same effect as exposure to a higher degree for a short time. Thus, dates over-ripened (dark colored and opaque) after exposure for five or six days to a temperature of 45 deg. Cent. have much the same appearance as do dates ripened for three days at 52 to 55 deg. Cent. The greener the date, the lower the temperature at which the ripening process must start. When mature dates which show none of the translucent appearance of the beginning of the ripening process are set immediately in an oven having a temperature of 48 to 51 deg. Cent., most of them soon darken and instead of ripening into soft, juicy dates, produce a tough, insipid product with a dull grayish appearance and leathery texture.



Views in the Laboratory of the University of Arizona in Which the Experiments for Ripening Dates by Incubation Were Carried Out.

Prof. Freeman says: "When these dates are first set in a moist chamber (which, however, must contain no free water) at 38 to 40 deg. Cent. for three or four days, a considerable portion of them will begin to ripen and show the normal translucence and softening. When this occurs, such as are beginning to ripen may be transferred to the higher temperature and promptly finished into a good quality of fruit. I was unable to start more than half of these green dates by this preliminary sub-temperature incubation on account of the molds which seemed inevitably to take possession of the fruit in the ripening trays at the end of about five days. Such dates, therefore, as showed no sign of ripening at the end of four days were considered worthless. It would be interesting here to know just what stage maturity marks the dividing line between the dates that would and would not ripen. Does it depend upon the amount of invertible sugar present or upon the first appearance of the inverting enzyme?"

After the date is well along toward ripeness, high temperatures are not so harmful except that they tend to darken the color and make the date sticky on the outside. After the date is ripe, the temperature may be raised until the date is candied. These candied dates, however, lose some of the characteristic date flavor and are, therefore, disapproved by most people. While high temperatures and over ripening darken the product and candy the dates, they also increase the keeping qualities. The very plump, light colored and juicy date that we have at the first completion of the ripening process is attractive in appearance and delightful to the palate, but many of these, if packed as such, will sour. It is best, therefore, to continue the ripening until the fruit is distinctly shrunken and the juice forms too strong a solution for the growth of yeast and bacteria.

If the ripening is continued until the dates are thus sugar cured they will keep indefinitely, provided they are kept in tight boxes in a dry room. Another and by no means unimportant effect of the temperature upon the dates which are ripened by this method is the destruction of insect eggs. Dates of the Arechti and Deglet Noor varieties, which had naturally ripened on the trees, were carefully selected with respect to quality and freedom from insects and were packed September, 1910, in tightly covered tin boxes lined with oiled paper. The boxes were then securely wrapped in oiled paper with a final wrapping of two layers of ordinary paper.

When the boxes were opened about December 15th, practically every date was found to be infested with one or more worms. There is no possible chance that these worms could have entered the boxes subsequently to wrapping, so they must have hatched from eggs laid on the dates before they were packed. Wherever naturally ripened Arizona dates have been packed and put on the market this same complaint has occurred. Worm-eaten dates have, therefore, been a rather serious handicap to the commercial development of our date industry.

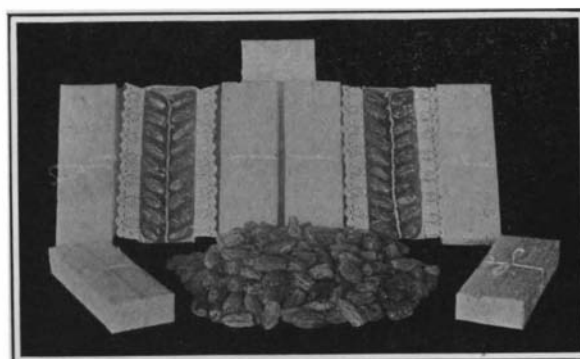
With the artificially ripened product, however, this difficulty is at once and completely overcome, for all insects and their eggs seem to succumb to the continuous moist heat of the ripening pans.

The ovens and ripening pans used are of interest. The oven was of zinc and had a double wall to prevent loss of heat. It was large enough to receive eighteen ripening pans holding about five pounds each. Two other ovens were used, carrying about twenty-five pounds each. The total capacity of the plant used was therefore about one hundred and fifty pounds. Flat graniteware pudding pans of five to eight pounds capa-

city were found most satisfactory for use as ripening pans. Tightly fitting tin covers were used on these, but graniteware covers do not corrode and would be better if they could be secured.

The influence of moisture is most important. The dates, after sorting, are washed to remove the dust and dirt which inevitably collects upon them. They are then drained thoroughly before being put into ripening pans. From poorly drained dates water is liable to collect in the bottom of the pans and cause sourness or stickiness of the finished product. Unless the dates are already shrunken, five or six hours' contact with free water will cause the skin to break on many of the fruits.

It is held that in a commercial plant it would probably be best to dry the washed dates for a few hours



Deglet Noor Dates, Grown, Ripened and Packed by the Arizona Agricultural Experiment Station.

on wire drying racks in an oven. The temperature should be about 40 deg. Cent., with free air circulation. When there is no moisture left on the exterior of the dates they are ready for the ripening pans.

It is advisable to place cloths or low wire screen racks in the bottoms of the ripening pans in order to absorb or raise the dates above any syrup that may drip from the fruits.

The soft or translucent dates lose about ten per cent of weight in ripening. This loss is water, and the bulk of the date decreases coincidently with a decided shriveling and wrinkling of the skin. The ripening pans are at first left open (usually twenty-four to thirty-six hours) until the skin begins to wrinkle perceptibly. The covers should then be fitted on tightly so that the remainder of the process of ripening takes place in a saturated atmosphere. When the covers are put on too soon souring is more likely to occur. An additional and more serious danger is that the dates ripen into exceedingly soft and juicy fruit. If packed in this condition such fruit will not keep. On the other hand, if the dates are dried down to packing weight, the shrinking flesh pulls away from the skin, leaving the latter to dry into an undesirable loose, papery shell.

As the date begins to shrivel in the early part of the ripening process, the skin will continue to cling to the flesh. This keeps the skin soft and tender and results in a finished product, which is a shrunken but still translucent and clean (not sticky) fruit. It is an important consideration in the production of a fancy confection date that it may be eaten from the hand without soiling the fingers.

The chemical study of this process is of special interest. The artificially ripened Deglet Noor date is decidedly a different product from that which naturally ripens on the tree. The former is an invert sugar date, while the latter, as has long been recognized, contains princi-

pally cane sugar. This may be seen in the following table of analyses:

TABLE I.—COMPOSITION OF DEGLET NOOR DATES

Lab. No.	Kind of dates.	Moisture.	Calculated to water-free material.		
			Cane sugar.	Fructose and glucose.	Total sugars.
4585	Naturally ripened....	Per cent. 17.23	Per cent. 61.30	Per cent. 26.72	Per cent. 88.02
4584	Drymummies(class 3)	21.21	60.73	22.75	83.48
4576	Artificially ripened (class 2).....	24.95	18.51	61.01	79.52
4581	Artificially ripened (class 3).....	28.75	13.65	72.22	85.86

The principal factors governing the amount of inversion are heat and moisture. The influence of each separately and in combination is shown in the following table from Prof. Freeman's paper on "Ripening Dates by Incubation."

TABLE II.—EFFECTS OF THE VARIATION OF HEAT AND MOISTURE ON INVERSION.

Lot and kind of dates.	Treatment.	Duration of incubation.	Temp of incubation.	Moisture content when ripe.	Calculated to water-free material.	
					Cane Sugar.	Total Sugars.
		Hours.	Deg. C.	Per Cent.	Per Cent.	Per Cent.
1 Soft mummies..	Soaked in water 7 hours at 49 deg. C.	117	49	29.15	12.69	85.37
2 Soft mummies..	Left dry.....	117	49	23.16	26.98	87.44
3 Soft mummies..	Soaked in water 7 hours at 20 deg. C.	117	20	33.44	37.80	85.82
4 Soft mummies..	Left dry (check)....	117	20	23.28	46.80	83.97
5 Hard mummies..	Soaked in water 7 hours at 49 deg. C.	117	49	28.75	13.64	85.86
6 Hard mummies..	Left dry.....	117	49	19.63	44.89	83.54
7 Hard mummies..	Soaked in water 7 hours at 20 deg. C.	117	20	25.91	47.52	82.59
8 Hard mummies..	Left dry (check)....	117	20	21.21	60.73	83.48

The dates used in these experiments had been lying in the laboratory at room temperature for about a month. However, the inverting process had probably been going on slowly in them for the two months after they first began to ripen. There were two classes of dates.

Those in which partial ripening had occurred and which were therefore somewhat soft, but not sufficiently ripe to be marketable, were termed "soft mummies," and those which had dried down to a hard and brittle condition were termed "hard mummies." Under natural conditions, slow inversion had occurred in both, but it seems to have been more active in those which were most advanced in ripeness. By deducting the cane sugar found from the total sugars present, it is seen that in wholly untreated samples 4 and 8, representing these two classes, there was 37.17 per cent of invert sugar in the soft mummies and 22.75 per cent in the hard mummies.

It is interesting, moreover, to note that the per cent of moisture at the time the analysis was made was slightly higher in the soft than in the hard mummies. The slow inversion in these two samples was most probably due to the fact that though there was sufficient heat and moisture for feeble activity of the inverting agents present, neither was at or near the optimum degree of intensity. When the temperature alone was raised there was an increased inversion amounting to 19.82 per cent in the one case and 15.84 per cent in the other. As to the influence of temperature alone, Table II gives only two instances, 20 deg. Cent. and 49 deg. Cent. In another experiment the result of

which is given in Table III, dates were first soaked in water until swollen and then ripened at intervals of ten degrees from 40 deg. Cent. to 90 deg. Cent.

TABLE III.—EFFECT OF DIFFERENT TEMPERATURES AND MOISTURE ON THE INVERSION OF CANE SUGAR.

Lot No.	Temperature of soaking.		Time soaked in water.		Temperature of incubation.		Time incubated.		Moisture.	Calculated to water-free material.			
	Deg. Cent.	Hours.	Deg. Cent.	Hours.	Per cent.	Per cent.	Per cent.	Per cent.		Acidity as H ₂ SO ₄ .	Cane sugar.	Fructose and glucose.	
21	Check				19.90	0.309	54.92	29.99					
27	40	12 ³ / ₄	40	95 ¹ / ₄	28.67	0.317	26.55	57.06					
28	50	13	50	79	31.41	0.354	9.94	75.01					
29	60	8 ³ / ₄	60	25 ¹ / ₄	30.86	0.334	24.88	59.00					
30	70	6 ³ / ₄	70	24 ¹ / ₄	34.52	0.403	23.73	58.43					
31	80	4 ³ / ₄	80	13 ¹ / ₂	29.08	0.382	38.67	45.36					
32	90	2 ³ / ₄	90	10	22.65	0.428	42.23	41.55					

It has been found that attempts to conserve canesugar by ripening the dates at or below 40 deg. Cent. result in prolonging the exposure necessary for the completion of the process and strongly increases the liability to

sour. On the other hand, at temperatures above 55 deg. Cent. (55 to 65) although not more than half of the time necessary for ripening at 50 deg. Cent. is required, great care must be exercised in order to prevent the production of dark colored, sticky dates. Although there is more cane sugar present, dates ripened at these high temperatures do not have so pleasing a flavor as do those ripened with less heat.

Prof. Freeman holds that the inverting agents of the Deglet Noor date do not reach their greatest activity under the conditions surrounding the trees as grown up to the present time in Arizona. Such of these dates as naturally ripen in this climate, therefore, having very little of their sugar inverted. Their inverting agents require for their greatest activity, temperatures distinctly higher than occur naturally during the ripening season in Arizona.

He claims that the ripening of a cane sugar date is a process separate and distinct from the inversion of the cane sugar present, and that conditions favorable for the rapid ripening of the Deglet Noor date may be produced artificially in an oven by regulating the degree of moisture and temperature. In this ripening process the tissues of the date are softened and the tannin is precipitated, thus relieving the date of its astringency.

It is further claimed that the same conditions of moisture and temperature used by Prof. Freeman in ripening Deglet Noor dates were also favorable for great activity of the inverting agents present in these dates. The artificially ripened product therefore differs from that naturally ripened in having nearly all of its sugar in the inverted form.

It is rather interesting to note how the application of the most modern scientific methods steps in at every point of industry, and seems to be calculated in this particular instance to establish in our own country the cultivation of a product, which for centuries past has come from the more tropical regions of the old world. The case might be regarded as a peculiar type of adaptation; since the palm tree cannot adapt itself to the climates in which we live to the extent of ripening its fruit for our use, the ingenuity of modern man steps in and substitutes, as it were, an artificial climate during the last stages of the ripening process. We might say, on the pattern of an old Mohammedan proverb: "If the palm will not adapt itself to the climate, then we must adapt the climate to the palm."

The University of Arizona is to be congratulated on the work done by its agricultural experimental station in developing this new process of ripening dates by incubation.

High Vacua: Their Production and Properties*

The Radiometer as a Delicate Pressure Gage

By W. R. Whitney

THE purpose of this article is to publish a few observations made in the research laboratory on some phenomena in vacua, as they may possibly be of interest to others who are working in the field of evacuated apparatus.

The subject has a double interest because at first glance it seems difficult to see how there can be much ground for study, or material and phenomena for useful investigation in such an apparently confined volume of nothingness as the vacuum of an incandescent lamp. The many actual developments from this lack of material are interesting, and there is the added interest, due to the fact that there are to be found in these lamps examples of many of the phenomena of gaseous ions which are receiving so much study in our day.

It has long been known that the life of an incandescent lamp is greatly influenced by the quality of its vacuum. In general, one may say that the better the vacuum, at least up to a certain point and until recently, the longer the life of the lamp. In the early days of lamp making, many schemes were devised to improve the vacua. This was then all the more necessary, as the mechanical methods of lamp-exhausting were very much inferior to present ones. The harmful effects of oxygen and water vapor, both of which reacted upon the filaments, were well known and many ways were devised for removing them.

What seems to be an especially interesting method of supplementing the vacuum pumps was the method of Malignani. This process, in its most perfect form, consisted in distilling into the bulb a small amount of some such substance as arsenic, iodine, or phosphorus. At the instant when one of these vapors was introduced, he passed a high current through the filament, the lamp being closed from the pump. This has long been the common commercial process for lamps which are to operate on voltages above 50, and many millions of lamps have been exhausted by its aid.

In the case of incandescent lamps where the voltage is above 50 for a fair brilliancy of filament, a blue discharge passes through the bulb and this blue quickly disappears when such vapors are introduced. The blue discharge seemed to be necessary for any considerable improvement of the vacuum, due to such vapors as phosphorus, and this led to the assumption that the gases still left in the lamp by the pump, were removed quickly during the blue glow and probably by the vapors which were at the same time being deposited on the glass. Although the facts were pretty well known, we performed experiments to study the phenomena. It was found that when the vacuum was measured by a McLeod gage, the sudden marked improvement of vacuum was easily proven. For example, in experiments carried on by Mr. Willey, of the laboratory, when the pump had produced a vacuum of 0.030 millimeter mercury and the cock leading to it was closed, a trace of phosphorus was distilled into the bulb while the filament was very hot and a blue glow had appeared; then about as quickly as the gage could be read the pressure had fallen to 0.002 or 0.001 millimeter.

*Paper presented to the American Institute of Electrical Engineers and published in its *Proceedings*. Copyright, 1912, by A.I.E.E.

That this improvement of vacuum is quite commonly produced when vapors of any kind are caused to condense in the space is not new. It even takes place markedly when the filament is first heated to very high temperature without added vapor, and a blue glow also passes through the lamp at the time. In improving the vacuum this latter way, however, it is known that the filament is injured and apparently a part of its material has been vaporized. This process soon causes blackening of the bulb by carbon.

This vaporization of phosphorus into the lamp at the moment when the pump has done its work, has long been the commercial method of finishing the exhaustion of incandescent lamps. The fact that even the carbon alone tended to the same end, though at the expense of the filament, being recognized, it became of interest to get a clearer view of this phenomenon.

In other words, if an incandescent lamp was burned while connected to a McLeod gage and the vacuum became poorer, the changes of vacuum might be measured by the gage from time to time. If, on the other hand, the vacuum improved so that the pressure tended to become less than the vapor pressure of mercury at the temperature of the gage, then the gage would not only not measure it, but the mercury vapor might even have affected the life of the lamp. When experiments were made to determine the effect of the vapor of mercury at the low pressures corresponding to a micron, which is the vapor pressure of mercury at 15 deg. Cent., very peculiar results were obtained and the lamps showed very early blackening. It looked as though even the presence of this constant mercury pressure was fatal to the lamp. Therefore the discovery of a more practical vacuum gage was desirable.

Without committing ourselves to a theory, we can describe one or two interesting experiments with mercury vapor. It was first discovered that an incandescent lamp grew black very quickly when attached to a mercury column which served as a gage to indicate evolution of gas. No such combination could be made to last over a few hours. The lamp blackened just as though it were in an imperfect vacuum. It is hard to see how the mercury can have any chemical effect upon the filament as oxygen or water have, and the effect is common to carbon and tungsten lamps. Many lamps were then made which were exhausted as perfect lamps are exhausted, except that a small quantity of mercury was left in the bulb. It was assumed that this would not interfere with the removal of air and moisture and might even assist by the washing effect of the mercury vapor, mechanically removing air. Lamps were also made in which a large quantity of mercury was placed, the lamp put into an oven above the boiling-point of mercury and the air washed out by the distilling mercury, no pump being used. When the mercury was nearly all removed the bulb was sealed off. This method, if no visible mercury is left in the bulb, is capable of giving good lamps, but where a visible drop of mercury was present the lamp would show a persistent blue glow and rapidly blacken, even below its normal voltage. In some cases it would arc between the leads, exactly as in the case of poorly exhausted lamps.

Lamps were also made to which were attached tubes which carried small globules of mercury. When these side tubes were short and straight, such as one or two inches, and the lamp was exhausted as well as possible on the pump, the blackening of the bulb started at once when the entire glass was at ordinary temperature. If now, the side tube with its mercury was submerged in different cooling mixtures, the length of time for a given blackening was increased. For example, at room temperature the lamp would be blackened so as to correspond to 80 per cent of its original candle-power in a few minutes. When the side tube containing the mercury was at 0 deg. Cent. this time became two or three hours; and when cooled in a freezing mixture at 20 deg. Cent. the life to 80 per cent was over 75 hours. Such differences were also noted when the pressure of mercury vapor was controlled by using cadmium amalgams, the amalgams higher in mercury corresponding to the shorter lamp life.

It was interesting to note also that by lengthening the side tube containing the mercury, the rate was decreased at which this filament material was deposited in the bulb.

In a set of experiments at ordinary temperatures the length of the side tube was increased and it was wound as a spiral. This reduced the rate at which the mercury could reach the bulb proper. In this case, instead of there being a continuous faint blue glow, as there is when the mercury is in a short side tube, the blue glow appeared and disappeared continuously and regularly. It looked as though there was a certain pressure of the vapor necessary before the blue discharge could occur and that when this was reached, the sudden discharge produced the blue and cleared the vacuum to a much lower pressure. Then mercury vapor distilled anew from the long side tube until again the necessary pressure was reached, when the process of clean-up repeated itself.

If the lamp bulb was kept very hot, the blackening was reduced and even done away with altogether, as though the deposition of the mercury vapor upon the glass by the discharge signalized by the blue glow could not take place. If, however, water vapor was present, even in very small amount, the blackening would take place very rapidly, even in the absence of mercury. In other words, most ordinarily, exhausted lamps will blacken relatively quickly if allowed to burn in a heated oven. In general, the hotter the oven the more rapid the blackening, but this process is largely, if not entirely due to imperfect exhaustion. All glass contains water which can be removed but slowly, even at relatively high temperatures. It has even been found that indefinite heating of a lamp connected to the vacuum pump is not capable of removal of all of this water. If exhaustion be carried on for a very long time at room temperature, then merely raising the temperature will cause liberation of more gas and after heating and exhausting to an equilibrium condition at say 200 deg. Cent. more water will be produced on heating to 300 deg. Cent. and still more at 400 degrees. For this reason it is customary to exhaust at as high a temperature as possible. At 400 deg. Cent. the ordinary glass has reached its limit, owing to the proximity of the softening point. For this reason we have had to exhaust the oven in which the lamps were