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The Roasting of Barley and Malt.

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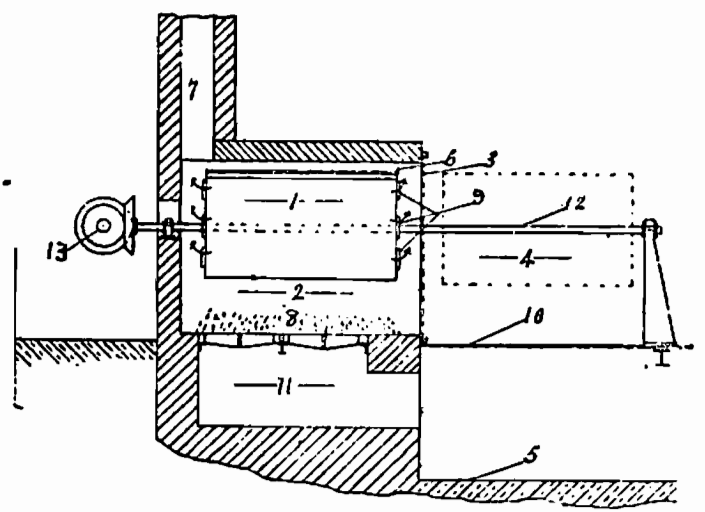
THIS industry, although a small one, presents many interesting features and as very little has been written about it a description of the process may not be out of place in the pages of this Journal.



1, Roasting cylinder in the firebrick oven, 2; 3, Sliding doors for closing the oven; 4, Cylinder in position for charging, taking samples, and emptying on to the concrete floor, 5; 6, Sliding door the whole length of cylinder used for filling, sampling, and emptying; 7, Chimney for conducting the smoke from the fire, 8, and the volatile products (steam and acid vapours) given off during roasting, and passing through the gauze openings, 9, at each end of cylinder; 10, Iron grating floor for breaking up the caked lumps of roasted barley as they fall to the cooling floor, 5; 11, Ash pit; 12, Square steel shaft for revolving the cylinder when inside and outside of oven; 13, Main driving shaft of roast cylinders.

Sometimes a movable coke fire, or two rows of movable gas jets, are used for heating the roast cylinder.

Procedure.—Assuming the roast house commences to work at 6 A.M., a coal fire is lighted on the firegrate, "8," the empty roasting cylinder being then outside the oven for receiving its charge of 8 cwt. of barley or malt. At 6.25 A.M., the fire having burned up sufficiently, the charged cylinder is pushed into position and revolved at about sixteen revolutions per minute, the sliding doors, "3," of the oven are then closed. As the heating of the cylinder proceeds careful attention has to be given to the fire in spreading it out evenly under the revolving cylinder by adding small quantities of coal at a time, so as to maintain the constant increase of temperature which is required. An experienced roaster knows from the volume, smell, and colour of the fumes when the doors of the oven should be opened, the cylinder drawn out, and a sample of the contents taken. In this case the time was 8.47 A.M. and the sample showed a satisfactory progress of the roasting; the cylinder was then quickly pushed back into the oven again, the fire attended to, the doors closed and the heating continued as before. In three minutes after this examination (8.50 A.M.), the fumes had so increased in volume, colour and smell, that it was thought advisable to remove the cylinder again and take another sample, which on examination showed that the roasting was proceeding too rapidly. The process was finished by revolving the cylinder outside the oven, the fumes, however, were increasing to such a degree at every revolution that it was deemed necessary to take another sample at 8.53 A.M., and this on examination was found to be of the desired chocolate colour. The required volume of cooling water was quickly thrown into the cylinder to stop further roasting and to prevent the contents being reduced to charcoal; the slide, "6," was quickly closed and the cylinder slowly revolved in order to mix the water thoroughly with the roasting barley. A large volume of steam is produced (as about 5—6 gallons of water are converted into steam) which finds an exit through the gauze wire openings, "9," in each end of the cylinder and through the leaky slide, "6," with the result that the whole building was filled with steam and pungent fumes for a minute or two. When the pressure of the steam was reduced, the revolving cylinder was stopped (8.55 A.M.) and its contents discharged on to the concrete floor, "5," and spread about with shovels and rakes to cool. When sufficiently cooled, samples were taken for examination; it was then screened, sacked, and weighed, and conveyed to the storage bins.

Five such roastings can be made from 6.0 A.M. to 6.0 P.M. each day, the time taken for each consecutive charge becoming less owing to the heat retained in the plant, the last charge taking only about 1 hour

and 54 minutes to roast. It is obvious that considerable economy in fuel could be effected if the roasting was continuous. One hundred and four pounds of Scotch coal (14,000 B.T.Us. per lb.) were required to roast the first charge of 8 cwt. of barley, the oven being cold at the beginning of the day's work.

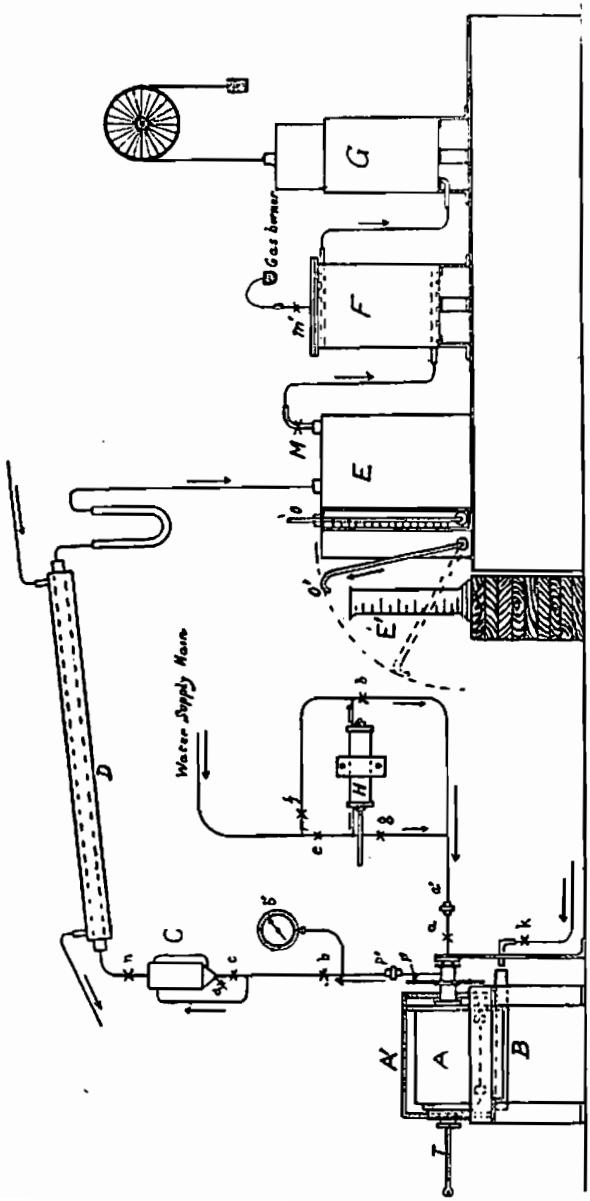
The temperature of the barley at the commencement of roasting is about 400° F., and at this point the starch commences to break up and in so doing gives out a certain amount of (exothermic) heat which gradually increases until the various compounds produced are reduced to charcoal and water. When this temperature of 400° F. is reached, no further external heat is required from the fire in the oven, as the temperature at the back of the oven is generally at about 930° F. and the front at about 700° F., hence the necessity of withdrawing the cylinder to the outside of the oven to keep its contents down to about 445° F. (caramel stage) at which temperature water has to be introduced to prevent it carbonising. The carbonising temperature appears to be about 480° F.

When there are a number of cylinders working in the roast house and all of them are charged and started at the same time, there is a flood of offensive, irritating fumes produced of a heavy acid, tarry character which are difficult to condense. The fumes, besides pervading the roast house throughout the whole day, are apt to become a nuisance in crowded areas.

It was considered necessary to investigate the composition and volume of the fumes evolved during the roasting process, and an apparatus for this purpose was accordingly set up. It will roast 4½ lb. of barley and is about 1/200 the size of the plant in general use.

After a few experiments the thermometer was dispensed with, as the rapid evolution of gas which indicates the commencement of roasting, at or near 400° F., became noticeable by the sudden expulsion of water from the tank, "E," into the measuring cylinder, "E¹." No further application of external heating of the cylinder is necessary, the volume of the gas collected constituting an indication of the caramel or chocolate colour stage of the roasting barley. Water is then injected into the cylinder to prevent carbonisation.

Before making an experiment, the tank, "E," is filled with water, the cock, "M," closed and the U-tube over tank sealed with mercury and the cock "*n*" opened. The cooling water in the condenser, "D," is turned on, the cock, "*h*," opened, the cocks, "*d*," "*c*," and "*b*," shut, the cock, "*a*," opened and the coupling nut, "a^1," disconnected. The automatic hydraulic pump, "H," must be tested to ascertain if one end is filled with cooling water for injecting into the roasting barley when required.



A, Roast cylinder with abestos covering, A'; B, Gas burner for heating the roast cylinder; C, Tar and condensed liquid separator; D, Reflux condenser; E, Water tank for collecting non-condensible gases; F, Purifier for eliminating the CO_2; G, Gas holder for measuring the purified gas; H, Hydraulic (automatic) pump for injecting a measured quantity of water into the roast cylinder worked by the pressure in the water supply main; T, Thermometer for taking the temperature during roasting.

The gas burner, "B," is lighted and the cylinder, "A," charged with 4½ lb. of barley, revolved steadily by means of a hooked rod in holes in disc, "P." As the heating proceeds the air will be discharged through the cock, "*a*," and the disconnected coupling nut, "a^1"; as soon as steam appears at this exit the cock, "*a*," is shut, and pressure will be gradually generated in the cylinder, which is indicated by the pressure gauge, "*b*." When the pressure reaches 15 lb. the cock, "*b*," is opened very slowly, the gases given off during roasting pass to the tank, "E," but on the way the condensible vapours are condensed by the reflux condenser, "D," and collected in the receiver, "C," where the tar separates from the acid liquor. Both can be drawn off for examination as the roasting proceeds and at the finish by opening the cock, "*d*." The volume of the non-condensible gases increase as will be seen from the rate of collecting which may be recorded by making marks of the level of the water (and noting time) on the paper scale at the back of the glass tube, "O." As a check the water displaced by the non-condensible gas can also be measured by the graduated glass cylinder, "E^1." For the first 55 minutes from lighting the gas burner, "B," very little non-condensible gas is given off, only about $\frac{3}{8}$-inch ($\frac{1}{6}$-inch = 170 c.c.) in tank, "E," it being principally steam which is condensed by the reflux condenser, "D," and the water collects in the separator, "C." When the water is expelled from the roasting barley, roasting commences and the speed of the chemical changes involved is indicated from the rate of collection of the non-condensible gas in tank, "E," viz. :—

From 55 minutes of lighting the gas burner, "B," $\frac{3}{8}$-inch of gas was collected.

From 60 minutes of lighting the gas burner "B," $\frac{3}{8}$-inch more was collected.

From 65 minutes of lighting the gas burner, "B," $\frac{3}{4}$-inch more was collected.

From 70 minutes of lighting the gas burner, "B," 3 inches more was collected.

At this stage dark fumes were noticeable in the U-tube over the tank, "E," which indicated that destructive distillation was taking place. If this was not checked by turning off the gas and applying cooling water (either internally or externally)—in this experiment externally—the caramel, woody fibre, and proteins of the barley would be quickly reduced to a mass of charcoal.

The cylinder "A" is lifted off and its contents discharged into a

shallow wooden box for cooling; when cold it is weighed and a sample taken for estimating the colour intensity.

Having noted the volume and temperature of the non-condensible gas in tank, "E," a sample of the gas was collected in a 100-c.c. gas burette and analysed with the following results:—

	Per cent.
CO_2	= 79·25
O	= 1·00
N	= 3·75
CO	= 16·00
	100·00

The gas-holder, "G," is lowered to its normal position and carefully balanced so that the slightest pressure will cause it to rise; next the cock, "M^1," of the inverted gas burner on top of the gas purifier, "F," is shut, the cock, "M," on top of water tank, "E," is opened, and a rubber tube is connected to the glass syphon tube, "O^1," of tank, "E," through which water is passed into tank, "E." This forces the non-condensible gas through the cock, "M," and through the lime purifier, "F," and finally into the gas-holder, "G," where it is collected for measurement and further treatment. When all the gas has been discharged from the tank, "E," the cock, "M," is closed, the balance weights are taken off the gas-holder, "G," and the gas is forced back into the purifier, "F." The cock, "M^1," on the top is opened, a light may be applied to the inverted gas-burner, and all the collected and purified gases burnt.

This non-condensible gas, on a large scale, need not be passed through a lime purifier for removing the CO_2, but may be passed up a chimney, or, if it is required to destroy any objectionable odour, it may be passed through a coke fire in the bottom of a chimney.

Roasting of 4½ lb. of Russian Barley in Experimental Cylinder.

Time.	Distillate collected.	Gas collected in tank.	Remarks.
	c.c.		
2.0 P.M.	—	—	Gas jets lit under cylinder and outlet cock M of tank opened to let air out and then shut.
2.26	—	—	Side outlet tube—hot, steam being given off.
2.30	57	—	Bend hot to condenser.
2.35	33		[given off.)
2.37	—	—	First drop from gas tank. (Indicates gas being
2.40	33	$\frac{1}{16}$″	Gas collected in tank. ($\frac{1}{16}$″ of tank = 10·16
2.45	38		[cub. in.)
2.50	32	$\frac{1}{8}$″	More gas in tank.
2.55	38	$\frac{3}{16}$″	More gas in tank. (Steady run of displaced water from tank indicates increased evolution of gas.)
3.0	35	$\frac{3}{8}$″	More gas in tank. [in U-tube.
3.5	27	$\frac{1}{2}$″	More gas in tank. Slight hydrocarbon fumes
3.6	—	—	Checked gas at burner back to mark.
3.10	52	3″ more gas	Fumes in U-tube increasing.
3.11½	—	—	Barley softening in cylinder—gas turned off.
3.12½	—	—	Cooling cylinder with water.
3.13	—	1¼″ more	Cooling water stopped—gas ceasing to be given off.
3.15	—	1¾″ more	Cylinder off for emptying.
		8″ =	Total gas collected.
	56 more distillate from receiver.		
	396		
	390 = total distillate when cold. Acidity as acetic acid = 1·4 per cent. Only a trace of acid tar as tem. was controlled. Colour of sample was above the standard.		

Results.

1·55 per cent. of gas.
19·00 „ distillate.
79·45 „ roasted barley.

100·00

By multiplying these numbers by 200 we obtain the quantities that would be given off from an 8-cwt. charge.

I hope what I have written will explain sufficiently the practicability of the apparatus for conducting further investigations on the roasting of barley and malt. Improvements in the construction of roast houses are much needed when the health of the operatives engaged in this industry is considered.

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