WATER FOR Grain Alcohol Distilleries

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The shortage of cool water for the continuous operation of grain distilleries converted to high-proof alcohol for war purposes has led many plants to water conservation and mechanical cooling. About 700 gallons of water are required for the processing and total recovery of feed by-products per bushel of grain converted to 95 per cent alcohol.

AT PRESENT the beverage alcohol (whisky) industry is completely converted to and operates full time on the production of high-proof alcohol, furnishing about half the total alcohol needed in our war program. The majority of the molasses alcohol plants are converting to grain or grain concentrate, and the new plants (if any) to be built by the Government are to be high-proof alcohol plants operating on grain. Of the raw materials used in distillery operations, water is one of the essentials; and since large quantities are required, these plants must be located where an adequate supply is available. In peacetime many of the distillers shut down during the summer months mainly on account of water shortage and/or its increase in temperature. With present conditions creating a large demand for alcohol and by-product feeds, this must be avoided. A review of the water demands of a high-proof alcohol plant operating on grain therefore becomes pertinent.

In modern distillery practice the conservation of both water and heat is essential, and as a result an economic balance is maintained through the re-use of water at various temperatures. The total water used in the larger plants, as in the case of Hiram Walker & Sons, amounts, in round figures, to 700 gallons for each bushel of grain processed. This includes water for processing, boilers, condensers, by-product feed recovery, and domestic services. The water demands of the various operations naturally vary with the temperature of the water, but on the basis of using well waters running 60° F. (16° C.) for the mashing, fermenting, and distilling departments, and using 70° F. (21° C.) river water for operating the stillage evaporators, the breakdown is substantially as given in Table I.

For the purpose of discussion, the waters used in a distillery may be divided into three main classes—namely, processing waters, cooling waters, and boiler waters. In many plants these waters all come from the same source but the general decline in the static level of ground waters throughout the country is forcing not only distillers but other processing plants as well to use surface waters whenever possible.

PROCESSING WATERS

In the main, distillers prefer ground waters for processing purposes—that is, for the mashing of grains and conversion of the solubilized starch to sugar, in growing their yeast and in the fermentation of their saccharine mashes by the yeast to alcohol. This processing water should be free of sediment, should possess no foreign taste or odor, and should be clean bacteriologically, even to the extent of meeting drinking water standards. It should also be chemically constituted in order to furnish the desired inorganic salts for optimum fermentations and, if chlorinated, should carry only a trace of free chlorine. Lime-soda ash treated waters should not be used for processing because they are too alkaline. A limestone-bearing type water is preferred because it contains those inorganic salts which are necessary for optimum conversion and yeast propagation—namely, the bicarbonates of calcium and magnesium with traces of other cations and a moderate quantity of sulfates. The effect of various salts in these operations is recognized by fermentologists, and a discussion of the subject would be too lengthy to include here. Most of these limestone-bearing well and spring waters also run low in bacterial count and are usually cool so that they may be used for cooling purposes, preferably after they have been treated to remove or stabilize the bicarbonate hardness. The analysis of a typical well water found satisfactory for the processing of cereal grains to whisky and high-proof alcohol is given in Table II.

It is not so essential today as it was years ago for the distiller to find a "natural" satisfactory processing water. By combining what is known regarding the inorganic salt requirements of yeast and the effect of various salts on the mashing and malt conversion steps with present day knowledge regarding treatment, he can remodel or reconstitute almost any available water supply to meet his demands and even his whims.

TABLE I. WATER AND STEAM REQUIREMENTS OF A MODERN GRAIN DISTILLERY PRODUCING HIGH-PROOF ALCOHOL

	Gal. Water per Bu.	Lb. Steam per Bu.
Processing[a]		
Cooking (batch-pressure) and sterilizing	36	36
Mash coolers, double pipe	78	...
Fermenter cooling (coils)	70	...
Stills, high-proof alcohol	94	100
Total processing	278	136
Stillage recovery (screenings and solubles)[b]		
Evaporators, stillage	430	87
Dryers	...	55
Power house[a]	12	...
Administration[a]		
Sanitary + air conditioning	5	...
Solid carbon dioxide[a]	5	...
Bottling[a]		
Sanitary + air conditioning	35	...
Grand total	765	...

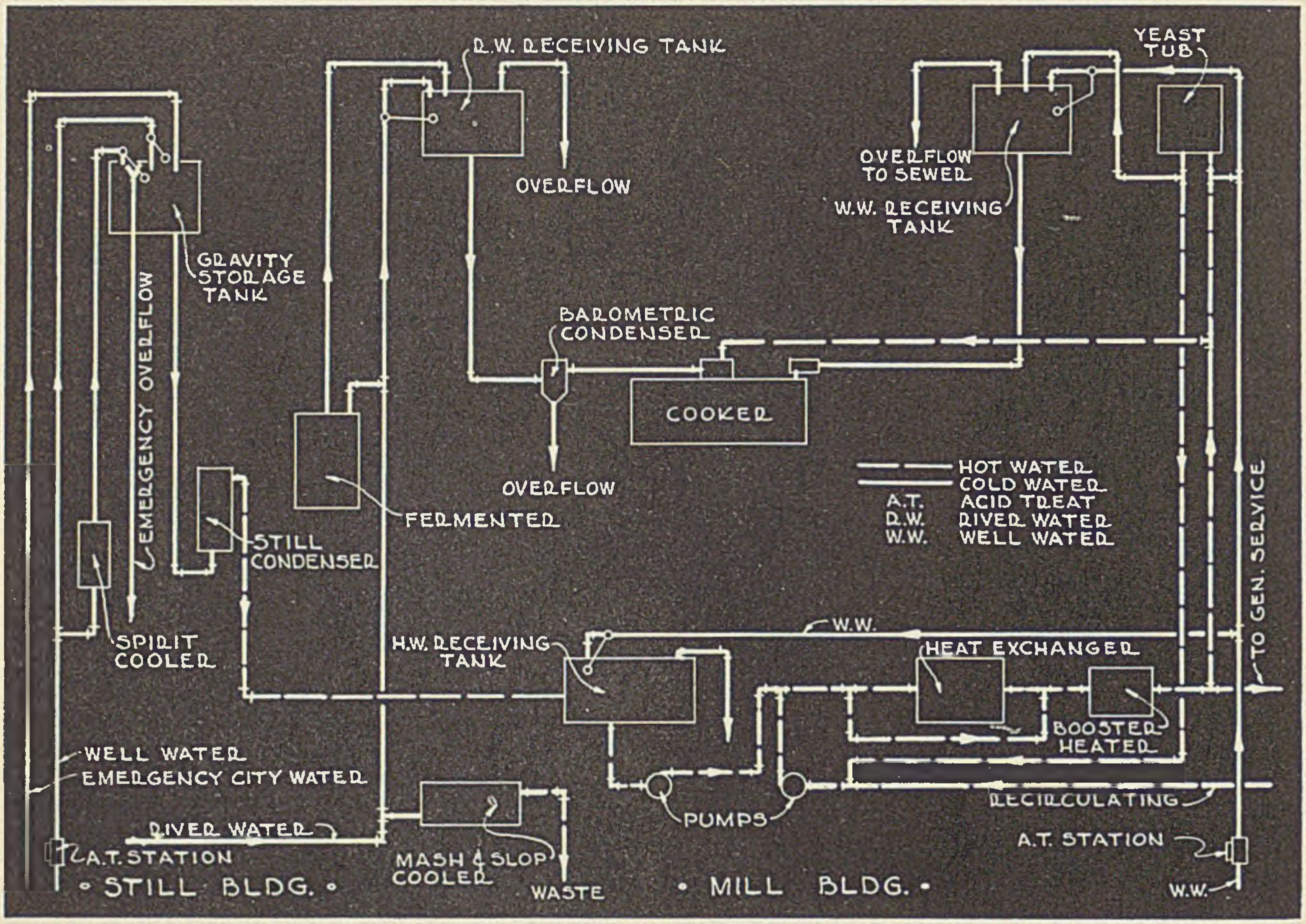
[a] Well water at 60° F.
[b] Illinois River water supply at 70° F.

COOLING WATERS

Cooling waters in most distilleries are treated in some way. If they are surface supplies, it may be necessary to filter them and perhaps even chlorinate them to eliminate the possibility of biological growths in heat exchangers and coolers. If the waters are warm, then it may be necessary to cool them through spray towers, refrigeration, or vacuum cooling.

Rice and Partridge (2) summarized the use of phosphate in treating waters at the Commercial Solvents Corporation plant in Peoria, Ill. They found that the increase in pH materially decreased corrosion.

At the Hiram Walker & Sons plant, well water is used in the whisky coolers and alcohol condensers. Inasmuch as the exit water temperature runs 140° to 160° F. (60° to 71° C.), it is necessary to acid- or phosphate-treat this cooling water. The hot water is recovered and used as hot water in the mashing process. In the double pipe, countercurrent mash, and slop coolers, untreated Illinois river water is used during the nine cooler months. This river water is low in bicarbonate hardness (Table II), offers very little scaling difficulty, and is therefore not treated. In summer, however, when the river water supply reaches 85° F. (29° C.) it is necessary to use well water (high bicarbonate, Table II), which means that it must be drawn from the acid treating system. This treated well water is recovered from the mash and slop coolers and used in the barometric condensers for drawing a vacuum on the cookers to cool the hot mashes (following pressure cooking) to 146–148° F. (63–64° C.) just prior to adding malt for conversion.



Flow Diagram of River and Well Water

If ground waters are to be used for cooling purposes (they are preferred by most distillers) they must usually be treated either with sulfuric acid or metaphosphate to eliminate partially or stabilize the bicarbonate hardness. This must be done in order to keep the system free of scale incrustations so that the cooling equipment will operate efficiently and prevent expensive maintenance and replacement costs. Both of these treatments have been used by Hiram Walker & Sons. At the lower temperatures sulfuric acid treatment has the advantage of lower chemical cost but the disadvantage of higher maintenance cost and the possibility of a certain amount of corrosion unless it is carefully proportioned and controlled. Metaphosphate treatment means a little higher chemical cost in most cases but is easier and cheaper to feed and gives more protection against corrosion. At the Hiram Walker & Sons plant, however, it did permit iron phosphate incrustations to collect in double pipe mash coolers. Metaphosphate has a distinct advantage over sulfuric acid in preventing scale and corrosion in hot water systems furnishing water at 180° F. (82° C.) or above.

The water used in controlling the maximum fermentation temperature at 90° F. (32° C.) may be either well water or river water, depending upon which is more available. In the hot summer months the use of warm surface waters is usually not feasible because it would require too much water and cooling coil surface.

This water need not be treated to remove or stabilize the bicarbonate hardness because it never reaches more than 90° F. (32° C.).

The hot water used in the Yeast Department to maintain the temperature of mashes undergoing lactic acid production, as well as the cold well water used to keep down the temperature of large batches of yeast under propagation, are collected; through the use of a thermostatic control valve, they are directed to the hot water recovery system if warm or to the well water recovery storage tank if cool. In summer when well water is used in the fermenter cooling coils, it is also collected and re-used through the well water recovery system.

The gradual decline in the ground water level in many parts of the country is leading distillers to substitute surface waters wherever possible. For example, instead of the standard heat exchanger type of mash coolers (double pipe, countercurrent) it is possible to reduce the temperature of hot mashes to the desired conversion point by vacuum cooling, using barometric and jet condensers. A large number of distillers have already gone to cooling water recovery systems (from mash, back-slop, and whisky coolers and condensers), and are cooling these recovered waters through spray towers and/or refrigeration systems. When the temperature of a surface supply of water exceeds that necessary for the heat exchanger type of cooling, this water may still be used for refrigeration equipment or for vacuum cooling although a larger quantity is required.

The successful use of lake water through a hot portion of double pipe coolers followed by the use of a spray tower and vacuum cooling system to give a water of 50° F. (10° C.) as practiced at a distillery in Bardstown, Ky., has been reported (*1*).

The water used in operating multiple-effect evaporators for the concentration of screened stillage may be of any type as long as it is not too warm and contains only a moderate amount of suspended solids. At the Hiram Walker plant in Peoria, river water is used in the barometric and jet condensers the year round although the temperature varies from freezing to 85° F. (29° C.). Naturally more water is required at the warmer temperatures.

BOILER WATERS

The powerhouse uses well water direct from one well in order to have a constant source of water with definite softening requirements. This water is conditioned by a hot lime–soda ash process capable of treating 3,500,000 pounds per day. The treated water, together with returned condensates, is fed to two Sterling bent-tube boilers (rated at 1379 horsepower each), delivering approximately 7,000,000 pounds of steam per day at 250 pounds pressure. This high pressure steam is passed through two turbines to develop electricity for the plant and deliver 80- and 15-pound processing steam to the distillery. The natural sulfate ion concentration in this well water is adequate to provide the A. S. M. E. recommended sulfate-alkalinity ratio. Operations have shown that the hot lime–soda ash process removes only approximately half of the silica; therefore internal anhydrous disodium phosphate treatment is given the boilers. This combination treatment prevents boiler scale and provides clean steam for processing. The steam quality is good enough to permit use of the condensate from the alcohol still calandrias for distilled water for reducing proof. Analysis of this water from the collecting tank shows less than 2 p. p. m. of solids and less than 0.1 p. p. m. of iron. An additional quantity of distilled water is required above that supplied by the alcohol still calandrias; therefore powerhouse condensate is redistilled in a multiple-effect water still. This practice eliminates the necessity of chemical treatment of the water fed to the water still. Research has indicated that cation and anion exchange material can be used to produce a satisfactory deproofing water from the well supply.

The quantity of steam required for producing high-proof alcohol from corn containing 12–13 per cent moisture at a recovery yield of 5.1 proof gallons per bushel, varies with the method of processing and the type of stills used. In the batch pressure cooking method, using modern continuous stills not equipped for vapor re-use, about 36 pounds per bushel of grain are required for mashing and sterilizing and about 100 pounds per bushel for distilling. The complete recovery of by-products requires about 142 pounds of steam per bushel of grain ground to obtain a total by-product feed recovery of 17 pounds per bushel of original grain ground (Table I). The processing of wheat or rye to high-proof alcohol requires about the same quantity of water and steam as does corn.

WATER SYSTEM

The well water supply at the Hiram Walker plant is taken from an underlying gravel strata, its temperature ranging from 56° F. (13° C.) in summer to 62° F. (17° C.) in winter (note the temperature lag). Three of these 50–60 foot wells are capable of furnishing a total of 7000 gallons of water per minute. City water of the same type as the plant well supply is available in limited quantity in case of necessity.

TABLE II. REPRESENTATIVE ANALYSIS OF RIVER AND WELL WATERS

	River Water	Well Water[a]
pH	7.8	7.0
Chemical analysis, p. p. m.		
Calcium	4.97	125.7
Magnesium	10.1	40.1
Sodium	23.9	24.2
Sulfate	42.0	153.7
Nitrate	5.3	23.0
Chloride	25.0	29.0
Alkalinity as $CaCO_3$	134.0	305.0
Manganese	0.0	0.0
Fe (filtered)	1.0	0.1
Silica	8.0	14.0
Suspended solids	27.0	None
Organic and volatile	98.0	...
Total dissolved solids	253.0	608.0
Total hardness	166.0	479.0

[a] H_2SO_4-treated water has a pH of 6.4–6.7 and contains 150–180 p. p. m. of alkalinity as $CaCO_3$.

The river water system includes traveling screens through which the water flows into a sump; from there it is pumped by centrifugal pumps delivering a maximum of 11,700 gallons per minute to the distillery. The river water temperature ranges from 33° F. (1.0° C.) in winter to 85° F. (29° C.) in summer. So far it has not been found necessary to treat this water to control biological growths in the exchangers.

Each water supply is kept separate in the distillery since it is necessary to change piping when equipment is shifted from one supply to another. This eliminates the possibility of cross connections which might lead to pollution of the well supply used for processing and drinking purposes.

This discussion does not warrant a review of the various types of ground water wells used in the industry. However, attention should be called to the lateral type water collecting system being installed by the Ranney Water Collector Corporation which has been found satisfactory by the Joseph E. Seagram & Sons distilleries as well as many other industries where it is necessary to obtain a large quantity of water from one structure or water from aquifers of poor permeability.

LITERATURE CITED

(1) Anonymous, *Spirits*, 5, 30 (1935).
(2) Rice, Owen, and Partridge, E. P., IND. ENG. CHEM., 31, 58 (1939).

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