Water-Supply and Irrigation Paper No. 179 Series L, Quality of Water, 14

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

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PREVENTION OF STREAM POLLUTION BY DISTILLERY REFUSE

BASED ON INVESTIGATIONS AT LYNCHBURG, OHIO

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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PREVENTION OF STREAM POLLUTION BY DISTILLERY REFUSE.

By Herman Stabler.

SCOPE OF INVESTIGATION.

This report gives an account of investigations carried on near Lynchburg, Ohio, to discover feasible means of preventing the pollution of streams by distillery refuse. Lynchburg is in Highland County, Ohio, a few hundred yards east of the East Branch of Little Miami River and about 60 miles northeast of Cincinnati. It has a population of a little less than 1,000. Above and below Lynchburg the East Branch of Little Miami River flows through an agricultural district, and as the town has no sewerage system the stream is not seriously polluted except by the distillery refuse. The investigation was therefore confined to the following subjects: (1) The processes at the distillery and the sources of pollution; (2) the effect of the pollution on the stream; (3) the economical disposal of distillery wastes in such way that there will be no pollution of streams.

ACKNOWLEDGMENTS.

This work was done under the cooperative agreement between the United States Geological Survey and the Ohio State board of health.[a]

All laboratory work, both chemical and bacteriological, on the analyses in table 1 (6 samples from East Branch of Little Miami River) was performed by officials of the Ohio State board of health under the direction of Dr. E. G. Horton, bacteriologist and chemist. All laboratory work by the writer was done in the laboratory of the Ohio State board of health. The investigation was directed by Mr. M. O. Leighton, chief of the division of hydro-economics, United States Geological Survey, to whom is due in very great measure the value of the results obtained. The investigation received the hearty support of Messrs. Freiburg and Workum, owners of the distillery, through their superintendent, W. M. Cleveland, and his principal assistant and chemist, G. L. Bering. Much of the value of the examination is due to the special facilities for work and information offered by these gentlemen at no little inconvenience to themselves.

The courtesy of the Hoffman-Ahlers Company, of Cincinnati, Ohio; the Platt Iron Works, of Dayton, Ohio, and the Yaryan Company and American Process Company, of New York City, in furnishing illustrations to accompany this report, is also acknowledged with thanks.

DISTILLERY PROCESSES AND SOURCES OF POLLUTION.

GRAIN DISTILLATION.

The distillery at Lynchburg manufactures grain liquors, including principally rye and bourbon whisky. The process of manufacture in such an establishment is generally about as follows: The grain, freed from husks or chaff and other impurities, is ground to a coarse

[a] Twenty-sixth Ann. Rept. U. S. Geol. Survey, 1905, pp. 215-217.

meal in roller mills, the fineness of grinding being varied somewhat with the grade of spirits to be produced.

Definite amounts of the meal are weighed out for "mashing" by Government internal-revenue officers and conveyed to cookers. The cooker is a closed iron digester, cylindrical in shape, horizontally placed, and provided with stirring apparatus.

The Hoffman-Ahlers vacuum mash cooker is illustrated by fig. 1. In operation with corn the cooker is about half filled with water (20 gallons of water being used for each bushel of grain to be mashed) and the stirring apparatus, seen within the shell of the cooker on the left and actuated by the belt pulley at the end of the machine, is started. Steam is then admitted, and the grain meal is introduced through the manhole on top. The manhole is then closed and steam forced in until a pressure of about 55 pounds per square inch is reached. To accomplish a thorough digestion, this pressure is maintained about half an hour after the steam is shut off. A vacuum pump connecting at the bell on top of the machine is then started and by reduction in pressure the contents of the cooker are cooled down to about 63° C. Ground barley malt mixed with a little water is then added and thoroughly mixed with the contents of the cooker for about half an hour. During this time the diastase of the malt acts upon the starch in the digested grain meal and converts it into maltose and dextrinous matter, the object of the distiller being to increase the maltose and decrease the dextrinous product.

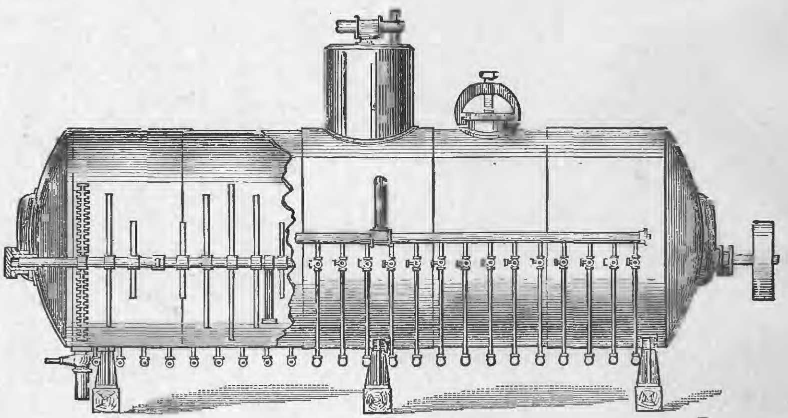

FIG. 1.—Vacuum mash cooker.

The distiller desires to produce from his grain the greatest possible amount of alcohol, and therefore fixes the narrow limit of 60° to 63° for mashing. A higher temperature would favor the production of a greater quantity of compounds not readily convertible into ethyl alcohol. In addition to the temperature, the quality of the malt and of the water has a considerable effect upon mashing. Distiller's malt is now generally specially prepared to produce a rapid and thorough conversion of starch, the germ of the malted grain being highly developed to produce a maximum diastatic power. The water used may retard or accelerate the action of diastase. Generally speaking, absence of organic matter or putrefactive products thereof and the presence of calcium sulphate are favorable to rapid conversion of starch.

After cooling the wort is conveyed from the cooker to the fermenting vats. These vats are large, open wooden tubs, cylindrical in shape and vertically placed. The wort is diluted to a desired consistency and there is then added to it a yeast mash, which produces a fermentation by which the maltose is broken up and forms, chiefly, alcohol and carbon dioxide. All the maltose having been disposed of, the residuum of diastase in the wort attacks the dextrinous matter, producing more maltose, which in turn is fermented. As in the previous processes, the production of a maximum amount of alcohol is kept to the fore. The yeast used is prepared from pure cultures to avoid loss of alcohol by the action of wild yeasts producing acetic, lactic, or other acids. The temperature is not made any higher than the point at which a healthy fermentation can be started, in order to avoid the production of an excess of aldehyde and fusel oil (the chief impurities in the manufacture of alcohol) and the loss of alcohol by evaporation. The maximum time allowed by law for fermentation is seventy-two hours. The distiller therefore uses an active top fermentation, by which all sugar is converted into alcohol as rapidly and as completely as possible. Carbon dioxide bubbles up from the surface of the liquid in the tubs in great quantity soon after fermentation is started, and a top coating, composed of the suspended matter in the wort, rapidly

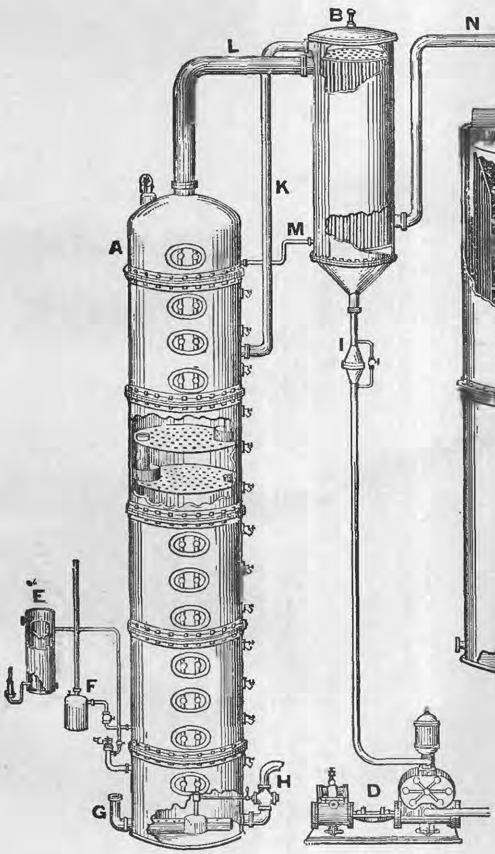

FIG. 2.—Continuous beer still.

forms to a thickness of several inches. As the fermentation nears completion the gas escapes in diminishing quantity and the top coating of suspended matter gradually subsides, leaving a light yellow liquor—a slimy mixture of solid matter, water, alcohol, fusel oil, aldehyde, acids, etc.—known technically as beer.

The beer contains a small percentage of alcohol, which is separated from the other products by distillation. This separation is now generally accomplished by means of a continuous distilling apparatus, modeled more or less upon the plan of the Coffey still. Such a still is shown in fig. 2. The pump *D* forces the beer through the check valve *I* into the tubular heater and condenser *B*. In passing through the tubes of *B* the beer is heated by the vapor which surrounds them and then passes into the still *A* through the pipe *K*. On entering the still the beer starts on a downward course, but is met by an upward rush of steam introduced through the perforated pipe *G*.

The still is fitted with an ingenious arrangement of perforated plates having tubular overflows (shown near the center of the illustration), which brings each particle of beer into contact with the ascending steam. Since alcohol is vaporized at a much lower temperature than water, the steam pressure (and consequently the temperature) is so regulated with observation of the steam gage *F* as to effect a complete vaporization of the alcohol, which, together with some water vapor, passes off through *L* into the tube chamber of *B*. Here the alcoholic vapor surrounding the tubes is cooled by the beer within them and some impurities are condensed and returned to the still through *M*. The purer product, however, escapes through *N* to the condenser and cooler *C*. As may be seen in the illustration, the alcoholic vapor takes a spiral course between two bodies of water, which cool and condense it until it emerges in the try box *J* as a mixture of alcohol and water, or raw spirits. The try box is locked and sealed by an internal-revenue officer, and the degree of concentration of the spirits may be read from a hydrometer floating in the liquor. It may be here mentioned that the distiller has no access to the spirituous liquor after it leaves the still, all subsequent operations being under the supervision of internal-revenue officers, who lock and seal all means of access until the liquor is barreled, gaged, and stored in a warehouse, from which it can be legally removed only by payment of the revenue tax.

The spirit product of the still accounts, of course, for only a small portion of the beer. The dealcoholized liquid, known as slop, gravitates to the bottom of the still and is blown out at *H*. At *E* is a contrivance, known as the slop tester, used in determining the efficiency of the still. The slop is variously wasted, pumped back for further use, fed to cattle, or treated for recovery of a dried stock food. It forms the great body of liquid waste from a distillery.

The crude spirit as it comes from the still contains aldehyde and fusel oil, which give it a nauseating odor and taste. These are partially removed by filtration through wood charcoal. The spirit is further purified by a second distillation in a rectifier. This is an intermittent process, the spirit being introduced by charges. The first vapor is chiefly aldehyde and fusel oil and is collected and sold as such. Of the remainder a part may be sold as alcohol or the whole may be reduced to a suitable proof and stored in oak barrels for the production of whisky by aging. During the aging process, which generally lasts from two to eight years, the residuum of fusel oil is broken up and the liquor acquires the characteristic aroma and taste of commercial whisky. Coloring matter is absorbed from the barrels by the spirit, which changes from colorless to whisky brown.

From the rectifier a small amount of waste slop and wash water passes off. This is dilute, and not usually sufficient in quantity to produce a nuisance. It will be hereinafter referred to as waste A. At Lynchburg this waste water was run directly into the stream. Its quantity was so small and its flow so irregular, as compared with the other wastes, that it received no detailed consideration in the investigation.

TREATMENT OF SLOP.

In the distillery at Lynchburg, as in many other distilleries, a portion of the slop from the still was used again as a diluent in the fermenting vats; the greater part of the suspended matter was screened out, dried, and sold as stock food; a portion of the remainder was fed to cattle; the rest was wasted. A detailed description of the treatment is given in order to furnish a complete understanding of the proposed method of slop disposal. This description may be considered as characteristic, though details vary somewhat in the practice of different distilleries.

For clearness and convenience the slops from corn and rye distillation, respectively, will be denominated "corn" and "rye" slops. As the treatment of the liquor is described, the various slops will be further designated by numbers and letters.

The slop as it comes from the still will be referred to as "slop rye 1" and "slop corn 1."

Slop rye 1 flows by gravity through a flume and pipe line to a receiving well at a building known as the "slop house;" thence it is pumped to a perforated brass sheet or screen, which is set at such an inclination that the greater part of the slop passes through and is carried away in a wooden flume to settling vats. This thin slop from the screen will be designated "slop rye 2." The coarser suspended matter, with some thin liquor, passes over the screen and falls into a wooden tub. This is slop rye 3.

Slop rye 2 is allowed to stand in settling vats for a few hours, when the supernatant, slop rye 4, is allowed to run into a pool of accumulated slops and filth. The heavier liquor from the vat bottoms, slop rye 5, is drawn off and fed to cattle, hundreds of which are kept for the sole purpose of disposing of this slop.

Slop rye 3 is forced into filter presses, which give a product of a thin liquor, slop rye 6, and damp feed, rye 7. The feed, containing about 60 per cent of moisture, is passed through a revolving horizontal cylindrical hot-air dryer, which reduces the moisture to less than 10 per cent. It is then sacked and sold as a concentrated cattle feed. Slop rye 6 joins slop rye 4 in the pool mentioned above.

Slop corn 1 flows over a preliminary screen set in the flume bottom, and is thereby separated into a thin slop, corn 1a, and a thicker slop, corn 1b. Slop corn 1a is pumped back to the fermenting vats, where it is used to dilute the wort from the cookers. Slop corn 1b follows the same course as slop rye 1, and is divided in exactly the same manner. The only variation in the treatment of the two is that slop corn 6, instead of passing to the pool, is pumped back to join slop corn 1a.

To recapitulate, the products are as follows:

1. Slops from still, rye 1 and corn 1.
2. Slops from preliminary screen for corn, corn 1a and corn 1b.
3. Slops passing to main screen, rye 1 and corn 1b.
4. Thin slops from screen passing to settling vats, rye 2 and corn 2.
5. Thick slops from screen passing to filter presses, rye 3 and corn 3.
6. Thin slops from settling vats discharged into pool, rye 4 and corn 4.
7. Thick slop from settling vats, fed to cattle, rye 5 and corn 5.
8. Thin slops from filter presses, rye 6 and corn 6.
9. Feed grains from filter presses, rye 7 and corn 7, to be dried.
10. Dried cattle food, rye 8 and corn 8, to be sacked and sold.

The cattle to which slops rye 5 and corn 5 are fed, and which subsist largely on this liquid food, produce quantities of semiliquid manure. A portion of this is hauled away to be used as compost on adjacent farms. The remainder, with all the more dilute wash water from the cleansing of the cattle pens, joins slops rye 4, rye 6, and corn 4 in an open barnyard pool, forming the chief liquid waste from the distillery. This pool drains, by a continuous stream and by large charges, into the creek, and will be referred to as waste B.

SOURCES AND CHARACTER OF POLLUTION.

It will be observed that there were two sources of pollution—waste A, a thin slop liquor of milky appearance, and waste B, a thin slop liquor mixed with filth from cattle stables. From 10,000 to 15,000 gallons were discharged each day, bearing into the stream from three-fourths ton to 1½ tons of solid matter.

The slop was essentially a corn or rye extract, containing all the ingredients of the grains except starch (which had been removed in the form of alcohol and carbon dioxide) in approximately the same proportions that the grains originally contained them. The following table of analyses of these grains, by Richardson, is taken from Thorpe's Dictionary of Applied Chemistry, vol. 1 (1890), page 490:

TABLE 1.—*Average analyses of corn and rye.*

[Based on 114 analyses of corn and 57 analyses of rye.]

Constituent.	Corn.	Rye.
Water	10.0	8.7
Nitrogen substance	10.5	11.3
Fat	5.2	1.9
Carbohydrates	70.7	74.5
Fiber	2.1	1.5
Ash	1.5	2.1
	100.0	100.0

As corn and rye contain about 55 and 45 per cent, respectively, of starch, the slop will receive 35 to 45 per cent of the grain as solid matter.

TABLE 2.—*Solid matter of corn and rye found in distiller's slop.*

Constituent.	Corn.	Rye.
Nitrogenous substance	10.5	11.3
Fat	5.2	1.9
Carbohydrates	15.7	29.5
Fiber	2.1	1.5
Ash	1.5	2.1
	35.0	46.3

As about 6.7 parts of water are used to 1 part of grain in the distillery processes, it is evident that the slop contained something less than 10 per cent—probably about 5 per cent—of solid matter.

Of the constituents named, those containing nitrogen make up the tissue-forming protein so important in animal food. Carbohydrates, fat, and fiber, digestible in greater or less degree, are producers of energy and fat. By the extraction of the starch the proportional content of protein is greatly increased, and the solid matter of distillery slop when separated from the water and dried thus becomes a valuable concentrated animal food. The ash also, chiefly potassium phosphate, has some food value.

Since these constituents have been taken largely from the soil in producing the grain, it is obvious that they will be suitable for use as a compost, which, by decay, would return to the soil much of the material taken from it. The use of these substances as food for animals, however, possesses much the greater monetary value.

Additional information regarding the constitution of distillery effluents is furnished by the following analyses of the slop, or "pot ale," of English distilleries, adapted from Trades Waste: Its Treatment and Utilization, by W. Naylor:

TABLE 3.—*Analyses of pot ale from English distilleries.*[a]

[Parts per million.]

SOUCIL AND HARVIE'S DISTILLERIES.

Constituent.	Soucil (Paisley).[b]	Harvie's.[c]
Dissolved matters:		
Total solids	39,378	28,955
Organic carbon	17,057	10,008
Organic nitrogen	2,373	2,041
Ammonia	180	90
Nitrogen as nitrites and nitrates	0	0
Total combined nitrogen	2,522	2,115
Suspended matters:		
Mineral	836	53
Organic	33,372	2,776
Total	34,208	2,829

[a] Naylor, op. cit., p. 152. [b] July 21, 1870. [c] March 15, 1872.

CRUDE SOUR POT ALE, SOURCE UNKNOWN.[a]

[Parts per million.]

Free ammonia	81
Albuminoid ammonia	55
Chlorine	388
Mineral solids	2,100
Volatile solids	23,850
Total solids	25,950

POT ALE, SOURCE UNKNOWN.[b]

[Parts per million.]

Total solid matter (soluble)	31,300
Ash	7,210
Phosphoric acid	1,990
Saline ammonia	100
Albuminoid ammonia	890
Sugar	400
Carbohydrates, aldehydes, and organic acids (lactic and succinic)	14,700
Oxygen absorbed in four hours	1,270

It would appear from these analyses that most of the suspended matter had been removed from all samples except that taken from the Soucil distillery. They indicate that nearly half of the solid matter of the slop is in solution, and that the total solids amount to between 5 and 10 per cent. The varying nitrogen values indicate that in some samples decomposition of nitrogenous matter had begun. The high values of nitrogenous matter and carbohydrates and especially the high ratio of nitrogenous to nonnitrogenous material argue well for the food value of the slop.

Almost the whole substance being organic, subject to putrefaction, and undergoing secondary fermentations, the ordinary sewage tests, both chemical and bacteriological, were considered suitable for tracing the effect of such an effluent upon the stream at Lynchburg.

[a] Naylor, op. cit., p. 153. [b] Ibid, p. 149.

EFFECT OF POLLUTING EFFLUENTS ON THE STREAM.

A reconnaissance of the East Branch of Little Miami was made from Lynchburg to Fayetteville, a distance of about 9 miles. At suitable intervals samples were taken for chemical analysis, and field tests for dissolved oxygen were made. In addition, plates were made in the field for total bacterial count on agar, for count of acid-forming bacteria on lactose litmus agar, and cultures of strong agar were made for subsequent transplanting and examination for the colon bacilli.

The reconnaissance developed the following physical evidences of pollution:

1. The condition of the stream above the distillery was very good. No evidence of pollution was apparent. The water was generally clear and nearly colorless.

2. The stream waters were colored a light yellow upon the entrance of the distillery waste. This yellow cast was noticeable for perhaps a mile, giving way gradually to a dark murky appearance, such as is commonly ascribed to stagnant water. The stream presented this darker appearance for about 6 miles.

3. A slimy sediment (or possibly a growth of some organism) covered the stream bed for 6 or 7 miles below the distillery. Near Lynchburg this was yellow and heavy. It decreased in amount downstream and changed in color to a dark brown or green.

4. At Bateman Bridge, 3 miles below the distillery, and at St. Martins Bridge, 6 miles below, the stream banks were edged with numbers of small dead fish.

5. An odor of putrefaction was very distinct a few yards from the stream at the two points above mentioned.

The stream, when examined, was somewhat above its average stage of flow. The foregoing conditions would, of course, be accentuated with decrease in flow. Fortunately the distillery is closed from July to October, inclusive. During the season of lowest flow, therefore, pollution is obviated. The difficulty is greatest during the late fall and early winter.

It was stated by a resident 6 miles below Lynchburg that the stench from the creek is at times so great as to be very offensive. Others stated that during the distillery season there is no fishing between Lynchburg and Fayetteville, but that during the summer numerous carp can be caught. At Fayetteville there were no visible evidences of pollution when the reconnaisance was made.

The results of the chemical and bacteriological determinations, together with the estimated dilution of the distillery effluent by the stream waters, are shown by the accompanying table. The chemical constituents were determined as follows: Dissolved oxygen, by the Winkler method in the field; oxygen consumed, by permanganate method, boiling five minutes; organic nitrogen, by the Kjeldahl method; free ammonia, by the distillation method; chlorine, by titration with silver nitrate, potassium chromate indicator; alkalinity, by lacmoid, boiling; solids, in platinum, drying at 100° C.; loss on ignition, by three-minute ignition at a shade under dull-red heat.

TABLE 4.—*Effect on East Branch, Little Miami River, of effluent from distillery at Lynchburg, Ohio.*

[Chemical constituents expressed in parts per million.]

	Dam above distillery.	Ford below distillery.	Lower bridge at Lynchburg.	Bateman Bridge.	St. Martins Bridge.	Fayetteville Bridge.
Numbers of samples	4292, 4286	4293, 4287	4291, 4297	4294, 4288	4289, 4295	4290, 4296
Distance below distillery	....	75 yards.	0.5 mile.	3 miles.	6 miles.	9 miles.
Dilution of distillery waste	....	1 in 150	1 in 150	1 in 250	1 in 300	1 in 350
Dissolved oxygen	7.6	5.9	4	2.3	1.4	6.9
Oxygen consumed	5.46	41.26	13.24	10.89	52	9.16
Organic nitrogen:						
Total	.75	6.59	2.09	1.49	15.13	.83
Dissolved	.66	2.58	.85	1.16	8.02	.8
Suspended	.09	4.01	1.24	.33	7.11	.03
Ammonia, free	.05	.05	.17	1.6	4.62	.14
Chlorine	4	3.5	5	3.7	7.2	5
Alkalinity	183	201	205	187	238	184
Solids:						
Total	289	425	305	272	483	282
Dissolved	272	346	294	266	431	273
Suspended	17	79	11	6	52	4
Loss on ignition:						
Total	67	171	74	70	238	68
Dissolved	61	112	63	59	172	73
Suspended	6	59	11	11	66	None.
Number of bacteria per c.c.	5,200	172,000	47,000	143,000	473,000	2,000
Acid-forming bacteria in 5 c.c. (lactose litmus agar plate).	Absent.	Absent.	Absent.	Absent.	([a])	Absent.
Colon bacilli in 1 c. c. (strong agar culture).	Absent.	Absent.	Absent.	Present.	Present.	Absent.

[a] Overgrown.

The results for St. Martins Bridge are far out of proportion to the others. There is almost no dissolved oxygen; oxygen consumed is 9.5 times the normal; suspended organic nitrogen is 79 times the normal; dissolved organic nitrogen is 12 times the normal; total organic nitrogen is 20 times the normal; free ammonia is 92 times the normal; chlorine is 1.8 times the normal; alkalinity is 1.3 times the normal; total solid matter is 1.67 times the normal; dissolved matter is 1.58 times the normal; total suspended matter is 3.06 times the normal; the loss on ignition is 3.6 times the normal for total, 2.8 for dissolved, and 11 for suspended solid matter; bacteria are 91 times as numerous as above the distillery. Colon bacilli were present in 1 cubic centimeter; the water had a dark, stagnant appearance; stench was noticeable some yards from stream; numbers of small dead fish were found lining the banks. The conditions at this place, 6 miles below point of pollution, constitute a very serious menace to property values, and render the stream unfit for use. These conditions are unusual and are not considered in the following discussion of normal pollution, and may be easily explained on the supposition that a few hours before the samples were taken a large amount of matter was discharged from the pool of filth at the distillery and had just reached the St. Martins Bridge.

In order to trace the diminution of evidences of pollution and the progress of the purification of the distillery refuse as it passes downstream, the results of analyses have been reduced to show percentage of normal values, the stream at the dam above the distillery being taken as normal. The results of this reduction are shown numerically in the following table:

TABLE 5.—*Percentage variation from normal in constituents determined in water taken at certain points on East Branch, Little Miami River.*

[Ingredients in water at dam above distillery taken as normal, or 100 per cent.]

	Ford below distillery.	Lower bridge at Lynchburg.	Bateman Bridge.	St. Martins Bridge.	Fayetteville Bridge.
Dissolved oxygen	78	53	30	18	91
Oxygen consumed	756	242	199	952	168
Organic nitrogen:					
Total	879	279	199	2,017	111
Dissolved	391	129	176	1,215	121
Suspended	4,456	1,378	370	7,900	33
Ammonia, free	100	340	3,200	9,240	280
Chlorine	88	125	92	180	125
Alkalinity	110	112	102	130	101
Solids:					
Total	147	106	94	167	97
Dissolved	127	108	98	158	102
Suspended	465	65	35	306	24
Loss on ignition:					
Total	255	114	104	355	101
Dissolved	184	103	97	282	....
Suspended	983	183	183	1,100	....
Bacteria per c. c	3,308	904	2,750	9,096	38

As the slop entering the creek is heavily charged with solid matter, suspended and in solution, nearly all of which is organic, it is to be expected that the total dissolved and suspended solids and losses on ignition would rise suddenly on the entrance of the distillery refuse. The fall in content of these matters, particularly those in suspension, during the first half-mile below the distillery, indicates that nearly all suspended matter is deposited upon the stream bed in that distance. This is evidenced by the heavy yellow sediment readily noticeable and gradually diminishing in quantity going downstream. The reduction in dissolved solids is also fairly rapid, in the first 3 miles being reduced to a trifle less than that above the distillery.

At Bateman Bridge and Fayetteville the total solid matter is less than above the distillery, and the content of volatile solids is only 4 per cent greater at Bateman Bridge and 1 per cent greater at Fayetteville. So far as these tests indicate, therefore, the variations from normal pollution is inappreciable more than three miles below the distillery (at Bateman Bridge), the stream having almost entirely purified itself by natural means. The stream has a moderate flow and consists of a succession of comparatively deep pools connected by rapids. These pools apparently act as a crude form of septic tank, and oxygen robbed from the stream by putrefying organic matter is gradually restored by aeration in the rapids.

The chlorine and alkalinity determinations serve only to show that the polluting effluent is somewhat higher in chlorine and alkalinity than the normal stream water. The chlorine seems to rise and fall in a manner that can not be attributed to any influence of the distillery refuse. The influence of the slop in increasing the alkalinity of the stream was first viewed with surprise, it being known that the slop as it comes from the still is distinctly acid. Tests made afterward, however, brought to light the fact that upon standing several days the slop changes (with lacmoid indicator) from an acid to a strongly alkaline liquor. The changes in alkalinity downstream from Lynchburg corroborate the conclusions already reached from the determination of solids.

The organic-nitrogen determinations are parallel with those previously discussed, inasmuch as they show an immense increase in organic matter with the entrance of the distillery refuse, followed by a gradual reduction in the pollution thus caused. Bateman Bridge, however, does not mark the limit of pollution indicated by these determinations. At that point the organic nitrogen is still twice as great as above the distillery, that in suspension showing the greatest proportional reduction. At Fayetteville the organic nitrogen is but little above the normal.

What has been said regarding organic nitrogen applies also to the oxygen-consumed test, an index to carbonaceous matter. The avidity for oxygen due to the distillery refuse has been nearly satisfied at Bateman Bridge, a reduction of less than one-third the normal oxygen-consuming power occurring in the 6 miles traversed between that point and Fayetteville.

The two chemical tests not already discussed, dissolved-oxygen and free-ammonia, are of more than usual interest in this case, because they mark the crisis in putrefactive action or the breaking up of carbonaceous and nitrogenous organic compounds into gases, water, and soluble mineral substances. The dissolved-oxygen tests, showing immediate decrease of a large proportion of free oxygen on the advent of the distillery refuse, serve to corroborate the unusual oxygen-consuming power of such refuse, as indicated by the oxygen-consuming tests. Bateman Bridge shows the lowest value for dissolved oxygen which can be attributed to normal state of pollution. It may be assumed, therefore, that the carbonaceous material has at this point been nearly all oxidized, further action of this kind being more than compensated for by oxygen naturally supplied to the stream waters. A gradual increase in dissolved oxygen is assumed to Fayetteville, where it is practically normal.

Comparing the stream action with a sewage-disposal system, Bateman Bridge may be looked upon as at the exit of a septic tank, further action being similar in result to that of oxidizing filtration. The diminution of dissolved oxygen may account for the death of the fish.

The tests for free ammonia indicate the absence of advanced putrefaction in the refuse that enters the stream. The nitrogenous matter is gradually broken up until a crisis is reached, as before indicated, near Bateman Bridge, from which point to Fayetteville the free ammonia decreases from 32 to 2.8 times the normal.

The bacterial counts indicate that the slop refuse contains a large number of organisms, probably such as produce secondary ferments; that stream conditions are not favorable to such organisms, and that they are reduced in number thereby; that the organisms originally present give place to bacteria which thrive on putrefying organic matter; that these bacteria assist largely in the purification of the stream and are not found, extensively at least, in the purified water at Fayetteville. The significance of the tests for B. coli communis is somewhat doubtful. It will be noted that this organism was found at but two points, Bateman Bridge and St. Martins Bridge, at which places all evidences of putrefaction were greatest. It is probable that its presence is due to the passage of a charge of concentrated filth from the cattle pens.

The important results of the reconnaissance of East Branch of Little Miami River from Lynchburg to Fayetteville may be summed up as follows:

1. The pollution by 1 part of distillery refuse in 150 parts of water is shown by a heavy sediment, deposited principally in the first mile below the distillery.

2. Such pollution causes a disagreeable stench for 2 or 3 miles along the stream and probably causes the death of fish.

3. The putrefaction of the polluting material in general is about complete 3 miles below the distillery, the stream at that point being similar in character to the dilute effluent of a septic tank.

4. Nine miles below Lynchburg the stream is apparently nearly as pure as it is above the distillery.

5. Large amounts of refuse discharged into the stream at other than flood stages produce extreme pollution, cause a strongly disagreeable stench, kill fish, and, in a word, render the stream unfit for its natural uses for more than 6 miles below the distillery.

DISPOSAL OF DISTILLERY EFFLUENT WITHOUT STREAM POLLUTION.

To dispose of the distillery refuse without polluting the stream, four easily apparent methods could be used with more or less success: Filtration, precipitation, fermentation, and evaporation.

FILTRATION.

Simple filtration for such refuse has never been attended with satisfactory results. Nearly one-half of the solid matter being in solution, mere straining can not produce satisfactory purification. Bacterial filters manipulated with special care and unusual precautionary measures on an experimental scale have given an effluent which does not produce appreciable pollution, but the tendency of distillery slop to sour by rapid growth of acid ferments makes such a method of disposal extremely difficult. Naylor describes a method of bacterial treatment which depends upon the principle that—

> the activity of one micro-organism is arrested by the introduction of media suitable for the rapid development of other competitive forms. * * * Putrid sewage, or sewage sludge, is introduced, the active anaërobic organisms in which come into competition with the acid-producing bacteria, and in a short time the action of the latter ceases; moreover, the ammonia and other unstable compounds in the sewage neutralize the acids if already present, the resulting putrid liquid becoming quite amenable to treatment on bacterial filters. The treatment as a whole is similar to septic treatment, but the "septic" tank is in this case not used for the purpose of liquefying sludge, but for that of rendering inert the acid-forming organisms. It is therefore better described as an antisouring tank.[a]

Experimental tests were made upon a small quantity of crude sour "pot ale," or slop, which was neutralized with lime, passed through a tank containing sewage, and then subjected to bacterial filtration. A decrease of 96.5 per cent in free ammonia, 88.3 per cent in albuminoid ammonia, 16.7 per cent in mineral solids, and 97 per cent in volatile solids was thus effected.[b] This may be considered a substantial purification. Naylor's method was applied with success to the waste from the brewery of the Hook Norton Brewery Company, Hook Norton, Banbury, England, and plants of similar character have been installed at several breweries in England, not, however, with universal success. The failure of such a process at the Old Brewery, Rothingham, resulted in experimentation on a large scale by H. McLean Wilson for a better method of treatment. He was able to secure a satisfactory effluent at this brewery only under the following process: (*a*) Yeast was excluded; (*b*) milk of lime in quantity equal to 45 grains per gallon of lime (643 parts per million) was added to produce a neutral liquor; (*c*) sludge was removed at frequent intervals; (*d*) the supernatant from anti-acid tanks was passed through double-contact ash filters; (*e*) ash-filter effluent was treated in a coke sprinkler in intermittent doses every five minutes for eight hours, amounting to 140 gallons per square yard per day; (*f*) effluent from coke sprinkler was strained through sand. This process resulted in purification of 96 per cent as measured by albuminoid ammonia, or 93 per cent as measured by oxygen absorbed in four hours at 80° F.[c]

Brewery liquors are of the same general character as distillery slops, though more dilute. It is probable, therefore, that the successful treatment of distillery liquors by such means as those described requires merely their adaptation to local conditions.

James Hendrick, in transactions of the Aberdeen congress, 1900, describes experiments with distillery refuse upon contact beds without preliminary treatment. The purification as measured by albuminoid ammonia and by oxygen absorbed in four hours at 80° F., respectively, was as follows: Seven contacts, 5 with coke followed by 2 with sand, 98.9 and 98.7 per cent; first six contacts, 97 and 98 per cent; first five, 96.4 and 97.9 per cent; first four, 89 and 95 per cent; first three, 73 and 65 per cent; first two, 40 and 61 per cent; first contact, 20 and 23 per cent. The last four effluents contained nitrates, as did the effluent obtained by Wilson in the brewery experiments.

[a] Naylor, W., Trades Waste, 1902, p. 153.

[b] Naylor, op. cit., p. 153.

[c] Wilson, H. McLean, Jour. Royal Sanitary Inst., vol. 25, pt. 3, p. 574 et seq.

The results of these English experiments, while indicating the practicability of bacterial filtration, with or without preliminary treatment, as a means of purifying such waste liquors as are produced by breweries and distilleries, demonstrate clearly that such a method of purification is very difficult and requires an extensive and costly plant and constant, intelligent supervision. The sludge produced in antisouring tanks is considerable and has but little actual value as a manurial compost. It may readily be the cause of a nuisance if not frequently removed and so disposed that its offensive odor shall not be objectionable.

Above all other objections to bacterial filtration of these wastes is the primary fact that this method is one of destruction and precludes the possibility of the recovery of any valuable by-products which they may contain. Distillery slop, as is well known, has appreciable value as a compost and a much greater intrinsic worth as an animal food. The high dilution of the valuable material and the fact that it is largely in solution prevent its more general use in either or both of the ways mentioned. The food or manurial value of the slop depends upon its content of organic matters, chief among which are the valuable compounds of nitrogen grouped under the term protein. The same matters form the element of nuisance in stream pollution by putrefaction after they enter bodies of water not relatively very large. Treatment in bacterial filters depends for its success upon the action of the bacteria-laden filtering medium upon the same constituents. In such treatment, however, the valuable material is regarded merely as an element to be destroyed as such, and is changed into gaseous, mineral, or stable organic compounds. This treatment is regarded as successful only in proportion as the food or manurial value of the organic carbon and nitrogen is destroyed. It is effective as a preventive of stream pollution only in so far as it renders devoid of value a product which with proper treatment may be made a source of considerable revenue. It follows that such a system must necessarily be a source of constant expense for which no direct monetary return can be expected. It is therefore a method of treatment to be employed only when more economic purification can not be accomplished. This being the case, and this field having already been well exploited in England, no experiments in filtration were made in connection with the investigation at Lynchburg.

PRECIPITATION.

Chemical precipitation as applied to distillery refuse is, in principle, a purification system of doubtful efficiency and economy. In practice, so far as known, it has never proved even fairly satisfactory in either particular. In his experiments upon brewery waste at the Old Brewery, Rothingham, Wilson tried lime, copperas, manganate of soda, and aluminoferric in various amounts and with varied combinations. As compared to lime alone, the use of the other precipitants served to hasten deposition of the precipitate, but made no practical difference in the effluent.[a] In every case the supernatant was unfit to discharge into a stream because of the failure of the precipitants to throw out of solution the large proportion of organic matter it held. In other words, the effect was similar to that of mechanical filtration or straining. These experiments show the futility of attempts to purify brewery or distillery wastes by means of the precipitants in common use. To be efficient as a means of purifying such liquors the precipitation must be carried on by means of a substance that will throw the organic matter out of solution. Even were such a substance known, the problem of disposing of tons of sludge daily would be left for solution. In the interests of economy the initial cost of the precipitant should be a minimum and its composition should be such that the sludge produced will have a maximum value. The solids of distillery slop have value either as fertilizer or as food stuff for stock, and in order to make the value of the sludge greatest the precipitant should also have one of these values, preferably the latter, since in that lies the greater value of the refuse. It is evident that the greatest economy might be secured by a high-priced precipitant that would produce a more valuable sludge. It is really the difference between the cost of precipitant and value of sludge that should be taken as a criterion of the economy of the process.

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[a] Jour. Royal Sanitary Inst., vol. 25, pt. 3, p. 574.

A successful—i. e., economical and efficient—purification of distillery refuse by chemical precipitation must therefore be accomplished by means of some substance as yet unknown that will precipitate the organic matter in solution as well as the suspended matter, and that shall itself be a suitable constituent of a fertilizer or a food stuff. Experimentation along the line of chemical precipitation should therefore include primarily a search for such a precipitant. In view of the manifest difficulties attending such experimentation, the improbability of success, and the success attending research in other lines, no attempt was made to exploit this method of purification.

FERMENTATION.

It might be inferred from the rapid souring of distillery slops by secondary fermentations that these could be utilized in the disposal of the slop by the production of lactic or acetic acids or some other resultant of fermentation. Such use has been made of brewery liquors for the preparation of malt vinegar.[a] Objections would be the great storage area required; the impurity of the product, several different fermentations being active; the great dilution of a product so obtained; the general low market price of products that could probably be so obtained, and the residual sludge from such a process, composed of matters otherwise valuable as a foodstuff, but rendered useless for such purpose by the fermentation process.

Here also the probabilities of success lying rather with another process, this means of disposal was abandoned without experimentation.

EVAPORATION.

The increased efficiency of modern evaporating apparatus suggested the possibility of conserving all the valuable food material of the slop by evaporation. This process possesses intrinsic merit absent in the other methods of disposal considered. The products of an evaporator would be: (*a*) A distillate of nearly pure water, incapable of polluting the stream and probably more valuable than the water of a natural supply for use in the distillery processes; (*b*) the solid matter of the slop, practically unchanged in composition. The basic principle of this method is practically ideal. Nearly perfect purification is attained by the conservation of the valuable material in the refuse. As the theory of this method of disposal was extremely attractive, and as a rough estimate of costs and values indicated large economic possibilities, it was investigated in detail.

AMOUNT OF SLOPS AND RECOVERABLE SOLID MATTER.

Table 6 shows the quantity of slops, both for rye and corn distillation, discharged at the brewery at Lynchburg, arranged by daily discharge and by discharge per bushel of grain mashed. The figures given represent, it is believed, within about 5 per cent the actual conditions and are therefore sufficiently accurate to be used as a basis of costs and values in estimating the economic possibilities of any disposal system.

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[a] Koller, The Utilization of Waste Products, p. 26.

TABLE 6.—*Daily discharge of slops at Lynchburg distillery.*

Source.	Slop (designation).	Total discharge.		Discharge per bushel of grain mashed.	
		Gallons.	Pounds.	Gallons.	Pounds.
Direct from still	Corn 1	77,000	651,600	44.0	372
Through strainer	Corn 1a	16,300	136,900	9.3	78
To screen	Corn 1b	60,700	514,700	34.7	294
Through screen	Corn 2	37,300	314,700	21.3	180
Over screen	Corn 3	23,400	200,000	13.4	114
Vat supernatant	Corn 4	7,300	60,700	4.2	35
Vat sludge	Corn 5	30,000	254,000	17.1	145
From presses	Corn 6	19,500	163,300	11.1	93
Pressed feed	Corn 7		36,700		21
Dried feed	Corn 8		17,500		10
To screen	Rye 1	61,500	542,200	44.2	377
Through screen	Rye 2	44,900	380,300	32.3	273
Over screen	Rye 3	16,600	143,900	11.9	103
Vat supernatant	Rye 4	14,900	125,200	10.7	90
Vat sludge	Rye 5	30,000	255,100	21.6	183
From presses	Rye 6	13,000	109,300	9.3	79
Pressed feed	Rye 7		34,600		25
Dried feed	Rye 8		11,600		8.3

As a means of estimating the amount of recoverable foodstuffs in the slop, hourly composite samples representing the entire working day were taken. Selected samples of the present slop product after screening, after pressing, and after the final drying were also taken for purposes of comparison and computation. Partial analyses of these samples were made in the laboratory of the Ohio State board of health, at Columbus, the results of which are shown in table 7.

The evaporation was effected by means of a water bath. A preliminary drying was given at 100° C. and a final drying at about 135° C. The figures show, therefore, values somewhat less than would be obtained by an accurate determination of solids under more favorable conditions. They will approximate very nearly, however, the true values for solid matter recoverable by evaporation.

In table 8 the proportional composition of the solid matter is shown, this having been prepared from table 7.

The amount of recoverable matter is shown in pounds per day in table 9, and in pounds per bushel of grain mashed in table 10.

TABLE 7.—*Recoverable solid matter in classified distillery slops.*

Source.	Slop (designation).	Sample No.	Dissolved.			Suspended.			Total.		
			Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.
To screen [a]	Corn 1b.	39	19.5	2.1	21.6	24.9	0.5	25.4	44.4	2.6	47.0
Through screen [a]	Corn 2	40	19.9	2.2	22.1	10.3	.2	10.5	30.2	2.4	32.6
Over screen [b]	Corn 3	42							94.7	3.1	97.8
From presses [a]	Corn 6	41	18.9	2.2	21.1	1.3	Tr.	1.3	20.2	2.2	22.4
Pressed feed [b]	Corn 7	43							426.4	7.2	433.6
Dried feed [b]	Corn 8	44							917.3	16.7	934.0
To screen [a]	Rye 1	34	19.8	1.9	21.7	27.4	.3	27.7	47.2	2.2	49.4
Through screen [a]	Rye 2	35	18.3	1.8	20.1	11.9	.2	12.1	30.2	2.0	32.2
Over screen [b]	Rye 3	37							89.6	2.8	92.4
Vat supernatant [a]	Rye 4	32	18.2	1.8	20.0	.1	Tr.	.1	18.3	1.8	20.1
From presses [a]	Rye 6	33	19.9	1.9	21.8	1.4	Tr.	1.4	21.3	1.9	23.2
Pressed feed [b]	Rye 7	38							307.3	5.1	312.4
Dried feed [b]	Rye 8	36							851.2	17.7	868.9

[a] Grams per liter. [b] Grams per kilo.

TABLE 8.—*Proportional composition of recoverable solid matter in classified distillery slops.*

[Per cent of total solid matter.]

Source.	Slop (designation).	Sample No.	Dissolved.			Suspended.			Total.		
			Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.
To screen	Corn 1b.	39	41.5	4.5	46.0	53.0	1.0	54.0	94.5	5.5	100
Through screen	Corn 2	40	61.0	6.7	67.7	31.6	.7	32.3	92.6	7.4	100
Over screen	Corn 3	42							96.8	3.2	100
From presses	Corn 6	41	84.4	9.8	94.2	5.8	Tr.	5.8	90.2	9.8	100
Pressed feed	Corn 7	43							98.3	1.7	100
Dried feed	Corn 8	44							98.2	1.8	100
To screen	Rye 1	34	49.1	3.8	43.9	55.5	.6	56.1	95.6	4.4	100
Through screen	Rye 2	35	56.8	5.6	62.4	37.0	.6	37.6	93.8	6.2	100
Over screen	Rye 3	37							97.0	3.0	100
Vat supernatant	Rye 4	32	90.5	9.0	99.5	.5	Tr.	.5	91.0	9.0	100
From presses	Rye 6	33	85.8	8.2	94.0	6.0	Tr.	6.0	91.8	8.2	100
Pressed feed	Rye 7	38							98.4	1.6	100
Dried feed	Rye 8	36							98.0	2.0	100

TABLE 9.—*Weight, in pounds, of solid matter discharged daily in classified distillery slops.*

Source.	Slop (designation).	Dissolved.			Suspended.			Total.		
		Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.
To screen	Corn 1b.	12,350	1,350	13,700	15,800	300	16,100	28,150	1,650	29,800
Through screen	Corn 2	6,200	700	6,900	3,200	100	3,300	9,400	800	10,200
Over screen	Corn 3							18,950	650	19,600
From presses	Corn 6	3,150	350	3,500	200	Tr.	200	3,350	350	3,700
Pressed feed	Corn 7							15,650	250	15,900
Dried feed	Corn 8							15,550	250	15,800
To screen	Rye 1	10,200	950	11,150	14,100	150	14,250	24,300	1,100	25,400
Through screen	Rye 2	6,850	700	7,750	4,500	50	4,550	11,350	750	12,100
Over screen	Rye 3							12,900	400	13,300
From presses	Rye 6	2,150	200	2,350	150	Tr.	150	2,300	200	2,500
Pressed feed	Rye 7							10,600	200	10,800
Dried feed	Rye 8							10,500	200	10,700

TABLE 10.—*Weight, in pounds, of solid matter discharged daily in classified distillery slop per bushel of grain mashed.*

Source.	Slop (designation).	Dissolved.			Suspended.			Total.		
		Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.	Volatile.	Fixed.	Total.
To screen	Corn 1b.	7.06	0.77	7.83	9.03	0.17	9.20	16.09	0.94	17.03
Through screen	Corn 2	3.54	.40	3.94	1.83	.06	1.89	5.37	.46	5.83
Over screen	Corn 3							10.83	.37	11.20
From presses	Corn 6	1.80	.20	2.00	.11	Tr.	.11	1.91	.20	2.11
Pressed feed	Corn 7							8.94	.14	9.08
Dried feed	Corn 8							8.89	.14	9.03
To screen	Rye 1	7.33	.68	8.01	10.13	.11	10.30	17.46	.79	18.25
Through screen	Rye 2	4.92	.50	5.42	3.23	.04	3.27	8.15	.54	8.69
Over screen	Rye 3							9.27	.28	9.55
From presses	Rye 6	1.55	.14	1.69	.11	Tr.	.11	1.66	.14	1.80
Pressed feed	Rye 7							7.61	.14	7.75
Dried feed	Rye 8							7.54	.14	7.68

From table 9 we find the total solid matter available each day on corn distillation to be 29,800 pounds (corn 1b), less 3,700 pounds (corn 6, used over in fermenting vats), or 26,100 pounds. Of this amount, 15,800 pounds (corn 8) was formerly recovered, leaving a total of 10,300 pounds run into the stream or fed to cattle. Possibly 100 pounds were wasted under the old recovery system. If, therefore, we deduct 300 pounds as waste under the extended system, we have provided a wide margin of safety and still have an increased product of 5 tons a day, or a total product of 12.9 tons a day.

For rye, none of the slop being used over, a proportionally larger product is obtainable. Deducting the 10,700 pounds (rye 8), recovered by the old method from the total of 25,400 pounds (rye 1), and allowing, as in the case of corn, 300 pounds for waste, we have an increased product of 14,400 pounds (7.2 tons), or a total product of 12.55 tons of dry solids.

METHOD OF EVAPORATION.

The first question arising which will affect the mode of procedure is in relation to the point of application of the evaporation process. What slops shall be evaporated? The stream pollution is caused chiefly by the waste each day of some 10,000 to 15,000 gallons of a fairly thin slop, the supernatant from the settling vats and the waste liquor from the rectifier. The remainder is now recovered or fed to cattle. Will it be more profitable to evaporate only those liquors that cause pollution or to apply the process to the entire slop output of the distillery? This question involves the abandonment of the cattle-fattening industry. It is generally conceded that this industry is financially precarious, being valuable chiefly as a means of disposing of slops. In some years it produces substantial profits; in others there are equally great losses. The cattle must be herded together in sheds, where the spread of communicable diseases is rapid. There is always great danger of loss by fire. Fluctuation in the market value of stock is another element of uncertainty. Although the business averages a small profit, few distillers would not be glad to exchange it for any other method of slop disposal that would not be a continued source of financial loss. Another objection to the cattle business is the great accumulation of manure, which from slop feeding is copious and in a semifluid condition. Great quantities are hauled away by farmers, but there is generally a remainder to cause a nuisance on the spot or to be run into the stream with the thin slops. From these considerations and the knowledge that the cost of evaporation is proportionally less with greater quantities, it is obvious that cattle fattening can well be abandoned if any part of the slop is to be utilized by evaporation.

Suspended matter will retard evaporation, causing a higher temperature for vaporization, forming scum, and having a tendency to adhere to the heating surface. In laboratory tests in glass and iron dishes much difficulty was caused by the burning of adhering particles in the evaporation of slops containing considerable suspended matter. Filtered samples or thin slops, such as those coming from the filter presses (corn 6 and rye 6), could be concentrated to contain only 50 per cent of moisture without serious difficulty. Tests on speed of evaporation of rye slops, the most difficult to treat because of the slimy nature of the liquid, showed an inappreciable difference between the speed of evaporation of the first half of equal volumes of distilled water and slop rye 4, the vat supernatant containing 100 parts per million of suspended matter. Rye 6, slop from presses containing 1,400 parts per million of suspended matter, was somewhat slower. A comparison of rye 6 (slop from presses), rye 2 (slop passing through screen), and rye 1 (slop before passing screen) showed that the volumes evaporated in a given time were approximately in the ratio 6:2:1. The suspended solids in these slops are approximately in the ratio 0.05:44:1. Although these experiments were not conducted with sufficient care to warrant great dependence upon numerical relations that might be deduced from them, they prove that the suspended matter seriously interferes with evaporation; that previous to evaporation the slop should be more thoroughly screened than at present; and that the screening should be at least as thorough as that effected by the filter presses.

In the conduct of an evaporation system, therefore, the first process should consist of passing slops rye 1 and corn 1 over a series of rotary or oscillating brass or copper screens. The screens should be designed to separate the slops into a thin liquid containing about 2.15 per cent of dissolved and 0.1 per cent of suspended solids and a thick, pulpy mass containing about 2.15 per cent of dissolved and 10 per cent of suspended solids.

Pl. I gives a view of an approved type of machine designed to filter-press distiller's slop. This machine is composed of 93 plates (one of which is shown in the foreground), which rest upon the iron frame of the press. Any two adjoining plates are separated by a filtering medium (a fine-brass screen or piece of stout cloth) and form a filter. The substance to be filtered is introduced through the opening in the center and is forced outward toward the perimeter. The clear liquid passes through the filtering medium and is drained off, while the suspended matter is retained between the plates.

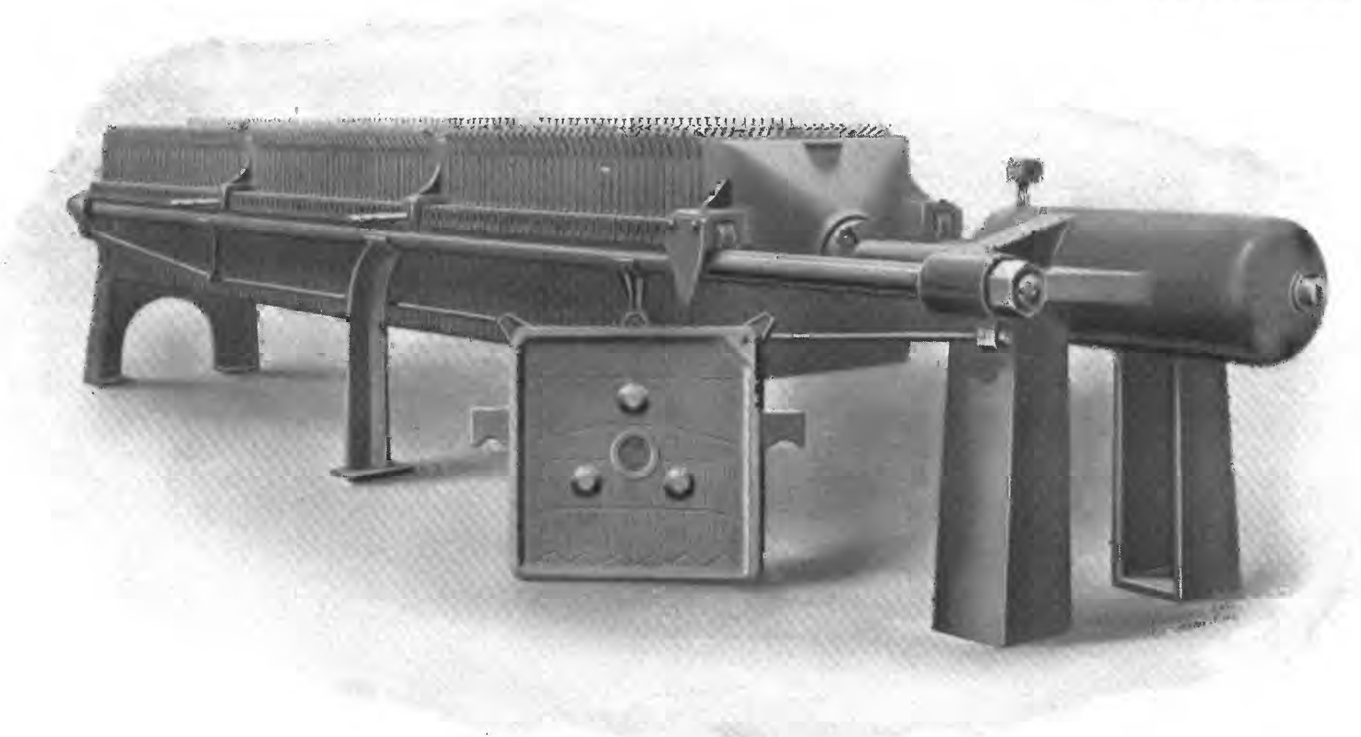
It will be observed in the illustration that the machine is arranged in three sections. The substance to be filtered is introduced at the left end of each section and is distributed to the various plates by a sort of screw conveyor operating in the central aperture. It is customary to force the material into the machine at a pressure of 150 to 200 pounds to the square inch. When the machine is filled in this manner, a further pressure is used to force the plates (which have been up to this time slightly separated) closer together and thus to reduce still further the moisture retained in the coarse material between the plates. This pressure is variously applied. In the illustration the hydraulic piston shown on the right is used for this purpose. A very high pressure is thus attained with consequent high efficiency in drying the suspended matter retained in the filter.

The moisture having been reduced as far as possible, the plates are separated, the caked material within is removed, and the machine is prepared for a new charge.

From this process two products are obtained: First, a thin slop of about the same composition as the thin slop from the screens; second, a damp, caked feed, half moisture and half solid matter. The first of these products should be pumped back to join the thin slop from the screens, the second should be conveyed to a mixer to be joined by the evaporated slop.

The thin slop from the screens should pass to a feed reservoir for the evaporator, where it should be joined by the thin slop from the filter presses and the thin slop from the rectifier, herein referred to as waste A. Waste A is an irregular flow of small amount. On this account it is excluded from the calculations. From this reservoir, in the case of corn distillation, 35,800 gallons will be carried back for use in the fermenters, this use of slop as a diluent in the fermentation process materially increasing the yield of spiritous liquors.

We have now reached that point in the disposal system where evaporation becomes necessary as a means of separating the water from the dissolved solid matter in the dilute slop liquors which are practically free from suspended matter. For this process vacuum



SMITH-VAILE FILTER PRESS

multiple-effect machines, of types such as the Yaryan or Chapman, are eminently suitable. The principles involved are primarily: (1) That the temperature at which a liquid will vaporize is decreased by decrease of pressure within the vessel containing it; and (2) after the temperature of a liquid has been raised to the point of vaporization an additional supply of heat is required to vaporize it, which supply of heat increases with decrease in temperature and will be given off when the vapor is condensed to a liquid.

Yaryan's triple-effect vacuum evaporator (fig. 3) may be taken as a type of this class of machines, the general principles of operation being alike in all. This machine consists essentially of three cylindrical chambers or "effects," in each of which is a series of coils of small tubing. Each effect is also provided with a separator to free the concentrated liquor from the vapor before it leaves the effect. A vacuum pump draws the vapor from the last effect and thus automatically regulates the pressures in the various effects. The operation is as follows: Steam is led into the cylindrical chamber surrounding the coils of the first effect, and the liquid to be evaporated is introduced within the first tube of these coils in a small but continuous stream. The surrounding steam immediately causes the liquid to boil, and the steam thus generated causes it to rush through the heated coils, where it becomes more and more concentrated as it progresses. Finally, the mixture of liquid and steam is discharged from the last tube into the separator. The concentrated liquor from the separator of the first effect passes to the coils of the second effect for further concentration. The vapor generated in the first effect passes to the chamber surrounding the coils of the second effect, where it is condensed and gives up its latent heat. The same operation takes place in each succeeding effect, the vapor from the final effect going to the condenser and vacuum pump, a high vacuum being thereby maintained in the coils of the final effect. This reduces the boiling point of the liquor in the coils below that of the surrounding steam, which, condensing, not only gives up its heat to the liquor in the tubes, but forms a vacuum of lesser degree in the next preceding effect. The relative pressure maintained in the various effects is automatically adjusted to accomplish a vaporization of the liquid in each effect, except the first, by means of the vapor generated in its own evaporation in the next preceding effect. The highly concentrated liquor from the final effect is removed by a magma pump as may be desired.

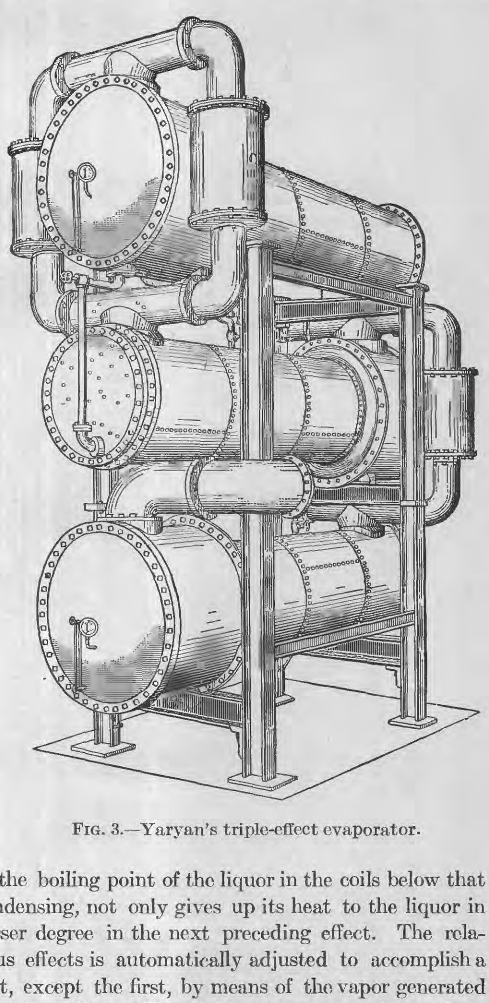


FIG. 3.—Yaryan's triple-effect evaporator.

This utilization of the steam generated by evaporation will accomplish in a triple-effect machine about three times as much evaporation with a given amount of fuel as the ordinary "single-effect" evaporator. Radiation and the expense of maintaining the low pressures will of course reduce the theoretical economy of the machine. It is claimed, however, that the Yaryan evaporators in practical operation, assuming that 1 pound of coal will vaporize $8\frac{1}{2}$ pounds of water, will evaporate the following amounts of water with 1 pound of coal: Double effect, 16 pounds; triple effect, 23.5 pounds; quadruple effect, 30 pounds; quintuple effect, 37 pounds.

Advantages of evaporators of this type are rapid circulation of liquid and consequent short time exposure to heat, low temperature of evaporation because of vacuum, and an arrangement by which a small quantity of liquid is exposed to an extensive heating surface. These advantages are of considerable importance in dealing with distillery slops, the organic compounds of which are likely to be broken up by high temperature and long exposure to heat, so as to impair possibly their food value. Within reasonable limits, by suitable arrangement of pressures, the temperature of vaporization may be regulated as desired, and thus any possible injury to recoverable material avoided.

Chief among the disadvantages are the great cost of the machines and their doubtful economy of operation in dealing with highly concentrated liquors.

In connection with the process of evaporation the matter of condensation of exhaust steam must be considered. For the proposition in hand this can be accomplished by about 350,000 gallons daily of cooling water to be used in connection with condensers of ordinary type. At Lynchburg this supply of water can probably be had at the cost of pumping from the adjacent stream, though it may be found necessary to sink shallow wells. As an extreme measure in case of limited water supply, cooling tanks or reservoirs may be constructed in which the water, heated by reason of its use as a condensing agent, may regain its normal temperature, and thus be made ready for use again. By such means an initial supply of water can be used over and over, a loss of only 2 to 10 per cent taking place daily through leakage and evaporation. There are in practical use many types of cooling towers in which artificial air draft or natural radiation is utilized for reducing the temperature. Simple open reservoirs are also used for such purpose, but these are generally considered to be less advantageous than specially constructed towers.

From the evaporation process, including condensation, we shall have two products, the first a magma or evaporated slop of 2,600 gallons on corn and 4,000 gallons on rye; and second, a distillate or condensed steam, amounting to 34,900 gallons on corn or 55,000 gallons on rye. (See table 11.) The distillate, a nearly pure water, is specially suitable for use in the mashing process, for which it has considerably greater value than a natural water. It should therefore be pumped to the cookers.

The magma, containing not more than 75 per cent of moisture (manufacturers of evaporators claim a reduction to 50 per cent moisture), should be passed to a tub and thoroughly mixed with the damp feed from the filter presses preparatory to drying. A cylindrical tub with central revolving vertical shaft having horizontal arms attached will prove a satisfactory mixer.

In this description of the disposal-recovery process we have now reached a point where all the waste from a distillery has been reduced to a pulpy mass of material suitable in composition for cattle feed. It remains only to prepare this for shipping. In the pulpy condition, although it is well adapted for immediate feeding, it is not marketable, because of its large moisture content and its liability to heat and ferment. To prepare it for the market, its moisture content should be reduced to about 10 per cent. In the present food-stuff process at Lynchburg this is accomplished by passing the damp feed from the filter presses through a hot-air drier, the product of the drier being sacked for shipment. With the process we are proposing, this treatment would be insufficient. Even in the present process considerable difficulty is experienced in the caking of the feed and consequent irregular drying. When it is considered that in the proposed process the material to be dried will contain more moisture and that much of it will be in extremely fine grains, it will be obvious that this difficulty would be enormously increased. It is proposed, therefore, to accomplish the drying in two stages. In the first a reduction to about 20 per cent of moisture will be obtained. The material should then be conveyed to a thrasher to break up all cakes formed, and finally to a second drier in which an even drying to a moisture content of 10 per cent or less may be accomplished. The usual types of hot-air or steam revolving feed driers and the ordinary feed thrasher would be suitable for this work.

A modern drier of considerable efficiency is shown in fig. 4. It consists essentially of a cylindrical steel shell provided on the interior with longitudinally placed shelves. Near each end of the shell is a steel tire which rests on friction roller wheels. These wheels are rotated by gearing or chain belting and they in turn rotate the shell. The drier as a whole is set on a gentle slope. Its operation is as follows: The wet material is introduced at the higher end by means of an intake hopper and falls to the bottom of the shell. It is then caught by the shelves and elevated by the rotation almost to the top of the shell and is then showered to the bottom again. This cycle is repeated again and again as the material slowly

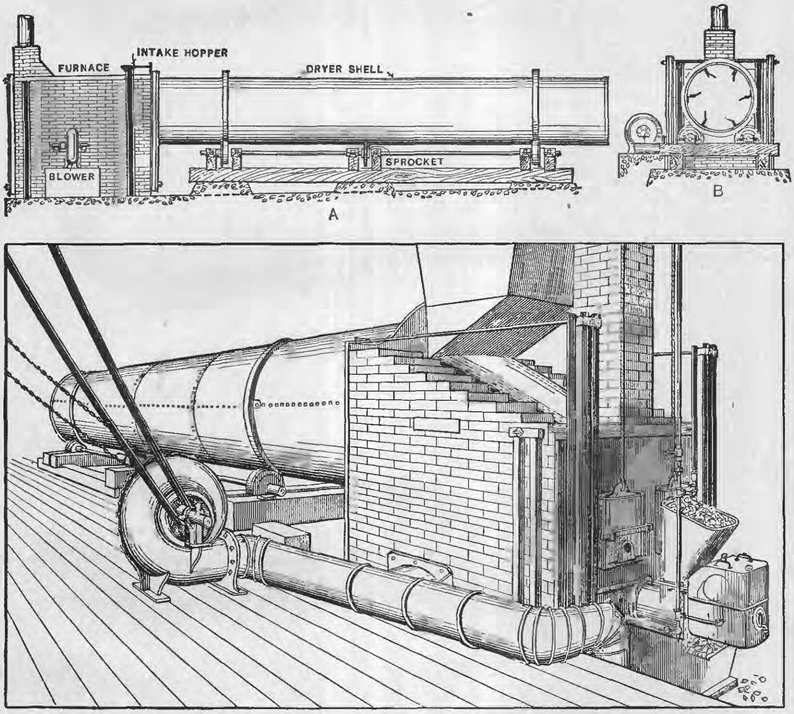


FIG. 4.—American process drier.

travels to the lower end on account of the slope of the machine and the high draft created by the blower. All hot gases pass through the drier on their way to the chimney, and as the material is showered from top to bottom of the shell it is brought in direct contact with the gases, thus accomplishing a rapid and thorough drying.

This drying process is the final preparation for sacking and shipment.

Table 11 shows the probable amount of the various slops and slop products (in pounds and gallons) and the amount of recoverable solids therein (in pounds), arranged by quantity per day, quantity per hour, and quantity per bushel of grain mashed. The figures shown are based upon measurements of quantities at the distillery, laboratory experiments, and general knowledge of the efficiency and capacity of the machinery described. Although these figures are unsubstantiated by practice, no such plant having yet been placed in operation, it is believed that they are fairly accurate and suitable for use in estimating costs and values.

TABLE 11.—*Probable amount of classified slops and slop products and recoverable matter under proposed system of disposal by evaporation.*

Source.	Slops and slop products.						Recoverable solids.		
	Gallons.			Pounds.			Pounds.		
	Per day.	Per hour.	Per bushel of grain mashed.	Per day.	Per hour.	Per bushel of grain mashed.	Per day.	Per hour.	Per bushel of grain mashed.
Corn.									
From still	77,000	7,000	44.0	651,600	59,200	372	33,300	3,030	19.0
Over screen	19,500	1,770	11.1	171,300	15,600	98	22,500	2,050	12.9
Through screen	57,500	5,230	32.9	480,300	43,700	274	10,800	980	6.2
Pressed feed				39,000	3,500	22	19,500	1,770	11.1
Slop from presses	15,800	1,440	9.0	132,300	12,000	76	3,000	270	1.7
For evaporation [a]	37,500	3,410	21.4	313,900	28,500	179	7,100	650	4.1
Evaporated slop	2,600	290	1.5	28,400	2,600	16	7,100	650	4.1
For first drier [b]				67,400	6,100	38	26,600	2,420	15.2
For second drier				35,300	3,200	20	26,500	2,410	15.1
Dried feed				29,000	2,600	17	26,300	2,390	15.0
Distillate from evaporator	34,900	3,170	20.0				None.		
Rye.									
From still	61,500	3,420	44.2	524,200	29,100	377	25,400	1,410	18.2
Over screen	13,900	770	10.0	124,200	6,900	89	16,400	910	11.8
Through screen	47,600	2,640	34.2	400,000	22,200	288	9,000	500	6.5
Pressed feed				28,800	1,600	21	14,400	800	10.4
Slop from presses	11,400	630	8.2	95,400	5,300	68	2,000	110	1.4
For evaporation [c]	59,000	3,280	42.4	495,400	27,500	356	11,000	610	7.9
Evaporated slop	4,000	220	2.9	44,000	2,400	31	11,000	610	7.9
For first drier [b]				72,800	4,000	52	25,400	1,410	18.2
For second drier				33,800	1,880	24	25,300	1,400	18.2
Dried feed				27,500	1,500	20	25,100	1,390	18.0
Distillate from evaporator	55,000	3,060	39.5				None.		

[a] Slop through screen, from presses, and waste A, less 35,800 gallons.
[b] Sum of pressed feed and evaporated slop.
[c] Slop through screen, from presses, and waste A.

As in the present system at Lynchburg, the thick slop from the screens should be filter-pressed to reduce the moisture content to about 50 per cent.

COST OF PLANT.

From the foregoing statement regarding the processes involved it will be inferred that recovery by evaporation involves the installation of costly machinery and the erection of an extensive plant. Chief in the list of machinery is the evaporating apparatus. Manufacturers were consulted and estimates secured on three different machines, as follows:

No. 1. Capacity, 3,250 gallons per hour. Price, $21,555. Triple effect, cast iron with copper heating surfaces. Three and four-tenths pounds of steam required to evaporate 1 gallon. Space required, 16 feet by 48 feet by 26 feet in height.

No. 2. Capacity, 3,500 gallons per hour. Price, $31,850. Quadruple effect, cast iron with brass heating surfaces. Two and eight-tenths pounds of steam required to evaporate 1 gallon. Space required, 18 feet by 24 feet by 27 feet in height.

No. 3. Capacity, 4,150 gallons per hour. Price, $25,000. Quadruple effect, cast iron throughout. Two and eight-tenths pounds of steam required to evaporate 1 gallon.

If we assume that 30 pounds of steam are equivalent to 1 horsepower hour, that 1 pound of coal will produce 7 pounds of steam, and that such coal can be procured for $2 per ton, the following data for the three machines are easily calculated from the figures in table 11:

TABLE 12.—*Cost of operating evaporators.*

Number.	Corn.			Rye.			Horsepower capacity of boilers required.	Cost per season.
	Hours per day.	Pounds coal per day.	Cost per day.	Hours per day.	Pounds coal per day.	Cost per day.		
1	11—	17,000	$17.00	17—	26,700	$26.70	369	$3,890
2	10—	14,000	14.00	16—	22,000	22.00	327	3,200
3	8+	14,000	14.80	13+	22,000	23.25	387	3,380

The average number of hours per day for corn distillation is 11, for rye distillation 18. Any one of these evaporators would therefore answer the purpose so far as time is concerned. In fact, there is little to choose between them. In about fifteen years the greater cost of operation on No. 1 would offset the greater first cost on No. 2, while in about seven years it would offset the greater first cost on No. 3. To state the comparison in another way, the additional capital invested in No. 2 will pay 7 per cent interest in decreased fuel bill, while the increased capital invested in No. 3 would similarly pay 15 per cent interest. In the daily cost of operating No. 3 is included 80 cents on corn and $1.25 on rye for lime to neutralize the acidity of the slop before passing it into a cast-iron machine.

Other considerations—such as floor space, labor, etc.—also enter into the problem. It is not the object of this paper to choose the best machine, and the foregoing discussion is merely intended to show that different types of evaporators manufactured by different firms will give results that are about equal viewed from an economic standpoint. In the estimates which are given later the foregoing have been averaged approximately, a theoretical machine costing $26,000 and operating at a daily cost of $15.50 for corn and $24 for rye being used as a basis of calculations.

Some additional expense would be incurred, including boilers of 400 horsepower capacity, costing about $2,000; a drier, $5,000; an addition to the slop house, $2,000, and installation, engineering, and incidentals not to exceed $5,000. These, it must be understood, are additions requisite to adapt the present plant to the manufacture of cattle feed by screening, filter-pressing, and drying, including the evaporation of thin slop previously wasted or fed to cattle in liquid form.

The estimated cost of present plant and additions is as follows:

TABLE 13.—*Estimated cost of food-stuff recovery plant at Lynchburg.*

Old plant.		Additions.	
Building	$2,000	Building	$2,000
Filter presses	2,000	Boilers	2,000
Drier	6,000	Drier	5,000
Miscellaneous	2,000	Evaporator	26,000
		Miscellaneous	5,000
Total	12,000		
		Total	40,000

The costs of the additions will apply to any distillery with a capacity of 1,750 bushels of corn or 1,392 bushels of rye per day. The total cost of installing a new plant throughout will be seen to be estimated at $52,000.

COST OF PROCESS.

The installation of an evaporating plant, with consequent increase in amount of feed grains, will incréase the greater daily cost of production. Two firemen at $1.50 per day will be required for the additional boilers; two men, one at $2.50 and one at $1.50, will be required for the evaporator; two additional men at $1.50 will be required for pressing and drying; two additional men at $1.50 for sacking and loading. For rye one-half should be added to the above, except sacking and loading, because of the extra hours, or for the average daily cost during the season one and one-eighth times the above should be taken. Fuel costs will also be increased. In the following table the seasonal average costs per day and total costs per season are shown.

TABLE 14.—*Cost of present and proposed feed grains.*

	Per day.			Per season.		
	Proposed grain.	Present grain.	Increase.	Proposed grain.	Present grain.	Increase.
Labor:						
Evaporation	$7.88	....	$7.88	$1,576	....	$1,576
Drying and pressing	9.87	$6.50	3.37	1,974	$1,300	674
Sacking and loading	8.57	5.57	3.00	1,714	1,114	600
Fuel:						
Evaporation	17.38	....	17.38	3,476	....	3,476
Drying and pressing	10.01	5.56	4.45	2,002	1,112	890
Total	53.71	17.63	36.08	10,742	3,526	7,216

VALUE OF PRODUCTS.

The value of the product depends of course upon its quality. The present corn grains have an average value of $18.25 per ton, or $20.16 per ton of dry substance. This is very nearly at the rate of 2⅜ cents per pound of protein and fat, a ton of dry substance at that rate being worth $20.45. The present rye grains have an average value of $13.25 per ton, or $14.40 per ton of dry substance. At 2⅜ cents per pound of protein and fat the value would be $14.08 per ton of dry substance.

To find the comparative value of the grains obtained by evaporation three rye and three corn grains were prepared and sent to A. Lasché, Milwaukee, Wis., for analysis, a number of similar analyses made by Mr. Lasché being at hand for comparison. The results of these analyses appear in table 15.

Proposed rye grain No. 1 was obtained by evaporating the slop rye 1. It represents the total product which we would expect under the evaporation scheme. Proposed corn grain No. 3 is a similar product obtained by evaporating slop corn 1b. It is with these two grains that our estimates will be concerned.

The other proposed grains were prepared with a view to maintaining the present grains as they are and making separate grains of the product of the evaporator. In preparing proposed rye grain No. 2 thin rye slops were evaporated to a sirup, the excess moisture being taken up with finely chopped wheat straw in the ratio of 0.37 part of straw to 1 part of dry substance in slop. Proposed rye grain No. 3 is merely the fine material of No. 2 after passing through a sieve. Proposed corn grain No. 2 was prepared in the same manner as the similarly numbered rye grain, the ratio of straw to evaporated dry substance being 0.73 to 1. Proposed corn grain No. 1 was prepared by evaporating thin corn slops to a sirup, taking up the excess moisture with damp feed from the filter presses, and drying. The ratio of dry substance in sirup to dry substance in damp feed was 1 to 1. The values of these grains, as shown at the bottom of table 15, indicate that such a method of preparing grains is feasible and would be attended with profit.

TABLE 15.—*Percentage composition of cattle-feed grains.*

	Present rye grain, average of three analyses.	Proposed rye grain No. 1.	Proposed rye grain No. 2.	Proposed rye grain No. 3.	Present corn grain, average of seven analyses.	Proposed corn grain No. 1.	Proposed corn grain No. 2.	Proposed corn grain No. 3.
Moisture	7.28	7.85	10.00	8.65	10.15	9.60	8.75	8.70
Protein	21.00	24.50	16.62	21.44	27.15	22.75	14.81	21.44
Fat	6.48	7.60	7.70	6.50	11.54	9.00	9.40	12.00
Free extract	8.11	36.55	45.38	38.75	8.10	36.60	38.75	26.92
Starch	6.24	19.10	....	....	....	....	....	25.44
Fiber	49.61	....	20.30	24.66	41.52	22.05	28.29	....
Ash	1.58	a 4.40	....	....	1.57	....	....	a 5.50
Total	100.30	100.00	100.00	100.00	100.03	100.00	100.00	100.00
Protein and fat in dry substance	29.64	34.83	27.02	30.57	43.06	35.11	26.53	40.93
Value per ton of dry substance per lb. of protein and fat	$14.08	$16.54	$12.84	$14.52	$20.45	$16.68	$12.60	$19.44

a Determined at laboratory of Ohio State board of health.

Returning to the value of the total product of grains obtained by the evaporation scheme, proposed rye grain No. 1 and proposed corn grain No. 3, we find that the rye has a much higher protein and fat content than the present rye grain. This is accounted for by the greater solubility of the proteids of rye. The same holds true of the free extract. It will be noted that ash, free extract, and fat have increased in amount in the new corn grain, while the protein has decreased. Rated at 2⅜ cents per pound of fat and protein, the new rye grain is worth $2.46 more per dry ton than the old, while new corn grain is worth $1.01 less per dry ton than the old. This does not, however, fully represent the true feed value of the new grains. Since the added part is almost all soluble, the digestibility of the new grains must be much higher than that of the old. As no data were available to determine the value of increased digestible nutritive material, the present rate paid for feed grains and the price of 2⅜ cents per pound of protein and fat were taken as the sole bases of value. Calculations based upon them are shown below.

TABLE 16.—*Amount and value of present and proposed feed grains.*

	Dry tons per day.		Value: Rye, $14.40; corn, $20.16 per ton.					Value: 2⅜ cents per pound protein and fat.				
			Per day.		Per season.		Total.	Per day.		Per season.		Total.
	Corn.	Rye.	Corn.	Rye.	Corn.	Rye.		Corn.	Rye.	Corn.	Rye.	
Proposed grain	13.15	12.55	$265.10	$180.72	$39,765	$9,036	$48,801	$255.64	$207.58	$38,346	$10,379	$48,725
Present grain	7.90	5.35	159.26	77.04	23,889	3,852	27,741	161.56	75.33	24,234	3,766	28,000
Gain	5.25	7.20	105.84	103.68	15,876	5,184	21,060	94.08	132.25	14,112	6,613	20,725

From the foregoing it will be observed that the gain in value is nearly the same whether calculated upon price of present grains or upon content of protein and fat, being 1.6 per cent less upon the latter basis.

As a secondary product of evaporation, on corn there will be 34,900 gallons and on rye 55,000 gallons of distillate, which may be utilized at the cost of condensing the vapor from the slop. Tests made by G. L. Bering at Lynchburg showed that this distillate will convert starch into dextrose ten minutes quicker than the best water now available at the distillery. It can be used in the mashing and cooking process, therefore, to excellent advantage, and it will be more than sufficient in quantity to answer this purpose. Under the multiple system of evaporation this product will be exhaust water and steam and will doubtless be suitable to discharge into the cookers without condensation. This is an asset that can not well be calculated in money value, but is well worthy of consideration as an economy resulting from the evaporation process.

PROFITS.

Having obtained approximate figures upon the cost of plant, cost of operation, and value of product, we are in a position to consider both amount and per cent of profits obtainable from the proposed methods of slop treatment.

From tables 14 and 16 the following is deduced:

TABLE 17.—*Seasonal value, cost, and profit for present and proposed feed grains.*

	Value based on price of present grains.			Value based on protein and fat content.		
	Value.	Cost.	Profit.	Value.	Cost.	Profit.
Proposed grain	$48,801	$10,742	$38,059	$48,725	$10,742	$37,983
Present grain	27,741	3,526	24,215	28,000	3,526	24,474
Increase	21,060	7,216	13,844	20,725	7,216	13,509

A profit of approximately $38,000 per season is therefore obtainable upon an investment of $52,000 in a complete plant, including evaporation. This represents a return of 73 per cent per annum. An increased profit of about $13,600 is obtained by adding a $40,000 plant for evaporation to the old plant, as described; this is at the rate of 34 per cent per annum. It must be remembered, also, that the foregoing estimates are based upon figures showing less than the true food value of the grains. A practical test demonstrating their greater nutritive properties should result in higher prices and increased profits. Furthermore, a considerable margin of safety is afforded by the calculation of the chief cost (fuel for evaporation) at 7 pounds of steam from 1 pound of coal. One pound of good coal should, in practice, produce between 8 and 9 pounds of steam.

The following tables show the value, cost, and profit per ton of dried product (9½ per cent for corn grains and 8 per cent for rye grains being assumed moisture content), and the value, cost, and profit per bushel of grain mashed. It will be observed that while the profit per ton is decreased 12 or 15 per cent the profit per bushel of grain mashed is increased 55 per cent because of the greater volume of the product.

TABLE 18.—*Value, cost, and profit per ton of feed-grain product.*

	Value based on price of present grains.			Value based on protein and fat content.		
	Value.	Cost.	Profit.	Value.	Cost.	Profit.
Proposed grain	$17.04	$3.81	$13.23	$16.85	$3.81	$13.04
Present grain	17.34	2.20	15.14	17.50	2.20	15.30
Increase	....	1.61	....	....	1.61	....
Decrease	0.30	....	1.91	.65	....	2.26

TABLE 19.—*Value, cost, and profit in cents per bushel of grain mashed.*

	Value based on price of present grains.			Value based on protein and fat content.		
	Value.	Cost.	Profit.	Value.	Cost.	Profit.
Proposed grain	14.5	3.2	11.3	14.5	3.2	11.3
Present grain	8.4	1.1	7.3	8.4	1.1	7.3
Increase	6.1	2.1	4.0	6.1	2.1	4.0

Table 17 shows that the cost of production is only two-ninths the value of the product under the proposed method of disposal. This method could obviously be applied, therefore, to a distillery two-ninths as large (capacity about 400 bushels of grain per day) with a very considerable degree of profit. In fact, there does not seem to be a minimum limit to the size of the distillery to which it could be economically applied, except the limit for economic operation of a multiple evaporator.

RESULT AT LYNCHBURG DISTILLERY.

A plant for the evaporation of slop was installed at the Lynchburg distillery late in the autumn of 1905. This plant was inspected by the writer while it was in process of construction, early in December, 1905, and again when in operation, on March 8 and May 1, 1906.

The slop is first passed over a brass screen containing 576 perforations to the square inch. This screen has an area of 21 square feet and a slope of about 9 inches in a length of 2 feet 8 inches. The slop passing over this screen is conducted to a second screen of similar area and somewhat greater slope.

The thick slop from the second screen is received in a wooden vat and pumped thence to be filtered in two 40-plate presses. Each press is 20 feet in length and 3 feet in diameter and has a net filtering area of 230 square feet.

The thin slop from both screens is received in large wooden tanks, from which it is pumped to the evaporator.

The evaporating apparatus is of chief importance and will therefore be described in some detail. The machine used is the Hoffman-Ahlers triple-effect vacuum evaporator, a view of which is shown in fig. 5. Each effect consists, essentially, of two chambers, A and B, A' and B', A'' and B'', connected by four large pipes, C, C', and C'', and also by a great number of tubes, placed within the steam chamber, E, E', and E''. The slop is introduced at F, into one of the pipes, C, of the first effect, and by the internal conditions is forced to circulate through the tubes (not visible in the cut) in the steam chamber E. These tubes are heated by steam under pressure, and the slop in passing through them is largely vaporized. The vapor passes out at the top of chamber A, through the large pipe G, which leads to the chamber E' of the second effect. The concentrated slop passes out at H, enters the second effect at F, and is further concentrated at a reduced pressure in the tubes D'. The vapor from the second effect is carried by the pipe G' to the steam chamber E'' of the third effect. The concentrated slop enters the third effect through one of the pipes C'' and is still further concentrated under a greatly reduced pressure. The vapor from the third effect is exhausted through the pipe G'', by the vacuum pump K, which serves to reduce the pressures as desired in the successive effects. The concentrated sirup from the third effect is pumped away to a convenient place by the magma pump L.

After several months of experimentation this apparatus is now in good working order. It is capable of treating more than 40,000 gallons of the thin slop in twenty hours (guaranteed capacity 2,700 gallons per hour) and reducing it 88 to 90 per cent in volume. It is now operated with 40 pounds of steam pressure in the first effect, a 3 or 4 inch vacuum in the second effect, and a 26-inch vacuum in the third effect. This apparatus costs, in place, $16,000. While this machine will dispose of all the waste corn slop at Lynchburg,

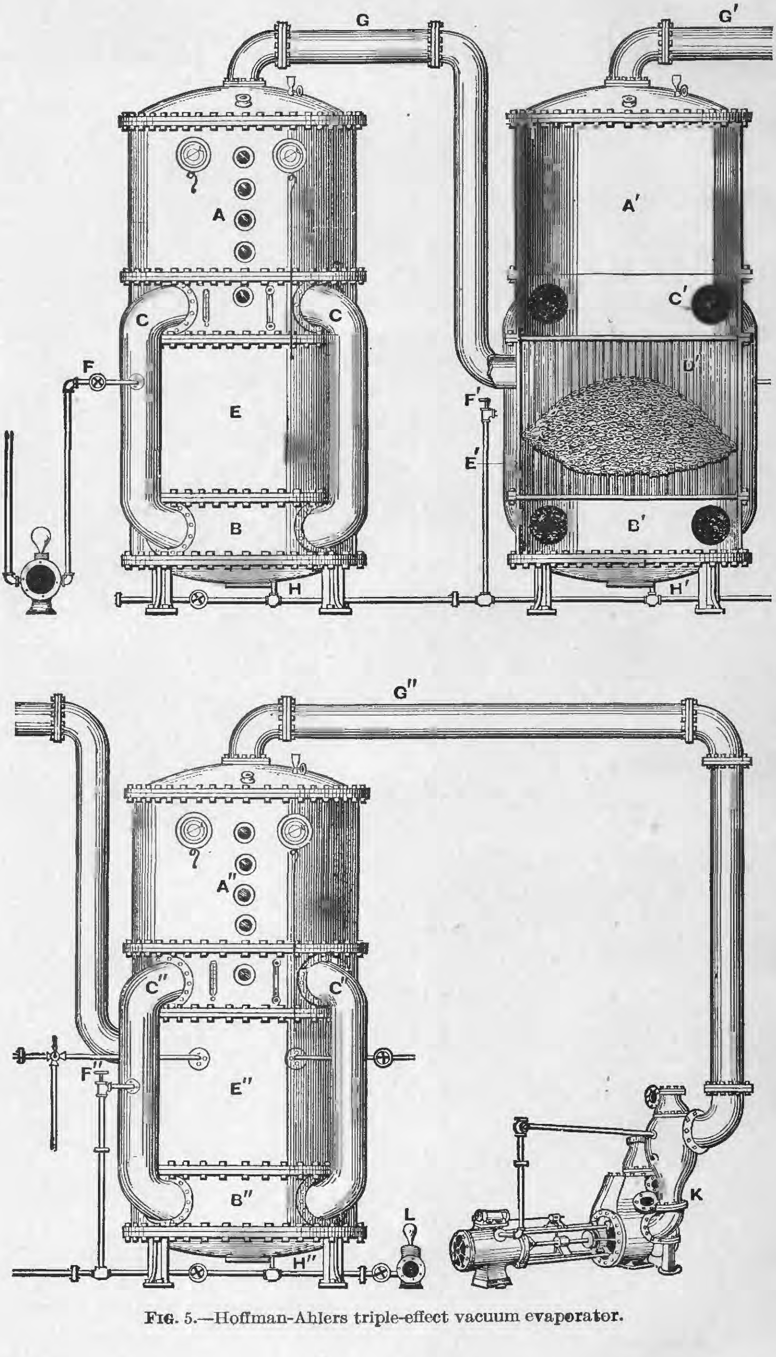


FIG. 5.—Hoffman-Ahlers triple-effect vacuum evaporator.

it may prove too small to evaporate all the rye slop. A small vacuum pan has been installed for further slop reduction when desired.

The magma from the evaporator is added to the feed from the filter presses, and the two are thoroughly mixed by passing through a screw conveyor 1 foot in diameter and 40 feet in length. It is then dried by passing through a direct-heat rotary drier, 40 feet in length and 6 feet in diameter, and a steam rotary drier, 20 feet in length and 6 feet in diameter. The product of these machines is placed in sacks for shipment.

The new apparatus consists of screens; evaporator and vacuum pan with accessory liquor, magma, and vacuum pumps; steam drier; addition to building; and a considerable amount of piping and a few minor pieces of apparatus.

Owing to difficulty experienced in the use of the new steam drier with the moist feed a machine has been specially designed to replace it.

The plant is so constructed that almost unlimited variations in operation can be secured. It will take a considerable length of time to develop the most economical plan of operation, as must necessarily be the case in any pioneer plant. Many possible economies have already suggested themselves, and others may be expected to develop with longer operation.

The evaporation system as installed at Lynchburg is an unqualified success, and even under present imperfect conditions a substantial profit upon the investment is being made. Although it is too early to figure definite profits, the indications are that the estimates in the body of this report will be realized and probably exceeded. In making these estimates a large factor of safety was used and the cost of plant and operation were purposely placed at a maximum figure. The installation at Lynchburg proves that the cost figures can be reduced in the main by about 25 per cent. The predicted increase in amount of manufactured food stuff has not yet been realized because all the slop has not been evaporated. The plant installed is apparently too small to evaporate all the slop at all times, but greater amounts will be handled when the mode of operation is perfected.

The predicted change in quality of manufactured feed has been realized. The new feed is sweeter and has a more attractive odor. It has a higher specific gravity. According to chemical analysis the protein and fat content for corn and the fat content for rye are slightly decreased, but this decrease is more than made up by the increased digestibility of these and the other constituents. Analyses of concentrated slop liquors made by A. Lasché, Milwaukee, Wis., are shown below.

TABLE 20.—*Analyses of concentrated rye and corn slop.*

	Rye.		Corn.	
	Per cent.	Per cent in dry substance.	Per cent.	Per cent in dry substance.
Moisture	86.40	....	75.31	....
Protein	3.025	22.17	6.497	26.32
Fat	.63	4.63	2.2	8.91
Free extract	8.7	63.95	13.6	55.08
Starch	.3	2.20	.8	3.2
Ash	.883	6.49	.293	1.22
Crude fiber	.062	.56	1.3	5.27
Total	100.000	100.00	100.000	100.00

The great per cent of moisture in the rye sample is to be accounted for by the fact that the evaporator had just been placed in operation. The 75 per cent moisture content of the corn sirup corresponds exactly with the predicted value, but it seems probable that both rye and corn sirups can profitably be concentrated in the evaporator to contain about 70 per cent of moisture. By comparing table 20 with table 15, it will be seen that the chief result in quality obtained by adding this sirup to the old grains is a large increase in free extract, a lesser increase in ash, and decrease in starch and crude fiber. The new grains will make the better cattle food.

With regard to stream pollution little can be said at present. Of course stream pollution can be entirely prevented by evaporating all the slop. The new plant at Lynchburg is not at present evaporating all the slop all the time, so that stream pollution still continues. By the end of the present distilling season better conditions will undoubtedly prevail, and probably all pollution will be obviated. The difficulties incident to the perfection of any entirely new system of manufacture are the cause of the present continuance of pollution.

SUMMARY.

The results of the investigation may be summed up as follows:

1. From the still and rectifier of a distillery about 45 gallons of waste slop liquor are discharged for each bushel of grain mashed. This liquor contains approximately 5 per cent (by weight) of solid matter, nearly half of which is held in solution. All the elementary compounds of the grain are represented in full quantity, starch excepted, the greater part of this substance being separated in the manufacture of the spirituous product.

2. One part of distillery refuse discharged into a stream of moderate fall having an average flow of 150 parts of water will produce a serious pollution for a long distance below the point of its introduction and may at times render the stream waters unfit for any use.

3. By screening out most of the suspended solids, nearly 10 per cent (by volume) of the slop may be converted into a dry cattle feed at a high rate of profit; an additional 50 per cent may be utilized as a liquid cattle food, generally with a slight profit; in the manufacture of some liquors a considerable quantity may be used instead of water in certain processes. From 10 to 40 per cent can not be profitably used and is run to waste.

4. Stream pollution by such refuse may be wholly avoided by means of evaporation recovery of cattle feed grains from the slops. By this method of disposal the entire slop product of a distillery may be utilized, the solid matter as a feed stuff and the distillate from evaporation as water for mashing.

5. As applied to a distillery using daily 1,750 bushels of corn for a season of 150 days and 1,392 bushels of rye for a season of 50 days, the following data regarding the process may be accepted as approximate:

a. Cost of complete recovery plant	$52,000
b. Annual profit over operating expenses on investment in complete plant for evaporation recovery, per cent	73
c. Cost of additional plant to add evaporation to recovery by screening	$40,000
d. Annual profit over operating expenses afforded by increased product, based on investment in additional plant to add evaporation to recovery by screening, per cent	34

6. A practical trial of the evaporation method at Lynchburg, Ohio, substantiates all the claims made for it and indicates that it will prove to be a rather greater source of profit than had been expected.

7. This system of economical disposal of slops can probably be applied successfully to any distillery large enough to create a serious nuisance by the discharge of its waste liquors into any but the smallest of streams.

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WS 161. Quality of water in upper Ohio River basin and at Erie, Pa., by S. J. Lewis. 1906. — pp., 6 pls.
WS 179. Prevention of stream pollution by distillery refuse, based on investigations at Lynchburg, Ohio, by Herman Stabler. 1906. 34 pp., 1 pl.

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SEPTEMBER, 1906.

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