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COLLEGE OF ENGINEERING
Department of Chemical and Metallurgical Engineering

Final Report

DISPOSAL OF FISH PROCESSING WASTES

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ABSTRACT

Small alewife rendering plants located in the Great Lakes area are confronting serious waste disposal problems. Generally these plants use the wet rendering process in which a very strong waste called stickwater is developed. This waste is so strong that it is usually not feasible to treat it by conventional waste treatment processes. It has been stated that stickwater represents over 90% of the BOD from such rendering plants. Fortunately it is possible to evaporate stickwater thereby producing concentrated fish solubles that have market value. It is probable that the remaining liquid wastes can be added to the stickwater and also evaporated to solubles. This has reportedly been done at menhaden rendering plants in the State of Virginia with the result that no liquid wastes were discharged from the plants. It should be possible to follow the same procedure at alewife rendering plants in the Great Lakes area. There is a cost problem however.

Where the rendering plants are large enough to incur the substantial investment required for multiple effect evaporation, the problem has essentially been solved by the experience in the State of Virginia. It is doubtful that many of the small alewife rendering plants in the Midwest can afford this investment, yet they must satisfactorily treat their wastes or eventually go out of business. Alternative evaporation methods have been proposed. These include submerged evaporation, submerged combustion evaporation and use of the Vincent evaporator. Another method named spray evaporation is suggested in this report. The suitability of all of these methods, including multiple effect evaporation, have not really been established for stickwater from alewife rendering plants. The suitability of triple effect evaporation and submerged evaporation for such waste are compared in this report using cost estimates based upon assumed data and information from the literature.

Really, however, no positive recommendation can be made concerning the best system for evaporating stickwater from alewife rendering plants in the Midwest until actual experience with this waste becomes available. Pilot plant data would be an acceptable substitute. It is therefore recommended in this report that necessary information be accumulated so that such a recommendation can be made. In general this would require pilot plant and laboratory studies to test each of the aforementioned methods, using stickwater from alewife rendering plants.

INTRODUCTION

Processing of industrial fish to produce meal and oil is an established enterprise in the major fishing areas of the United States. Generally it is only marginably profitable although the fish meals and oils that result are useful products. At the present time a number of small and medium sized plants are rendering alewives and other fish in the Great Lakes area. The alewife population of the Great Lakes has increased enormously in recent years. At least for the present, there is an adequate supply of these fish to support a rendering industry based upon them. Indeed, in the summer of 1967 large numbers of alewives died in Lake Michigan and littered the shores to such a degree that nusiance conditions occurred from the resulting bad odors.

Unfortunately, fish rendering plants often develop strong, foul smelling wastes. These are mostly liquids and gases, although small amounts of solid wastes are also produced. The liquid wastes can have very high Biochemical Oxygen Demands (BODs) and the gases often contain strong odors (5). When designing and operating fish rendering plants in the Midwest, it has been general practice to neglect the waste treatment requirements. Common rationalizations offered are that the fish business always produces odors, hence these odors are the "stink of prosperity," or—fish come from the lake so returning untreated fish processing residues to the lake is no different from that which occurs naturally. These attitudes no longer apply. The increasingly stringent regulations of pollution control authorities now require that these wastes be reduced in strength before being discharged. In some instances the cost of waste treatment procedures may be so high that the rendering plants are no longer profitable.

The purposes of the present study are to collect information regarding waste treatment systems for fish rendering plants and then to recommend research efforts that would lead to feasible waste treatment processes. These research efforts would be particularly directed towards solving waste treatment problems of small fish rendering plants in the Midwest area of the United States.

RENDERING PROCESSES

The amounts and kinds of wastes produced depend upon the type of rendering process used. There are many processes available for rendering waste animal tissues. Some of these have been adapted for fish rendering. Furthermore, new rendering processes are continually being developed in order to increase the value of oils, protein and other products that can be recovered. It is now becoming necessary to reexamine old processes or to develop new ones with the objective of reducing air pollution problems that can result from operation of these processes.

Stansby (1) classifies the currently used processes as follows:

- wet process
- dry process
- solvent processes
- digestion processes

The wet process is known to have been used over one hundred years ago in this country (4), it is still probably the most prevalent. It is well adapted to rendering oily fishes such as alewives, is suitable for continuous operation, and is used in the Midwest area at the present time. Both fish oil and meal are formed as saleable products. Strong odors and strong liquid wastes are produced. This process will be discussed in detail later in this report since it is the rendering process in which most of the present waste problems occur from fish rendering. The chief waste produced by wet rendering is stickwater.

The dry process is adapted only to very small operations. Solvent processes such as that of the VioBin, azeotropic type are not yet widely used for rendering in the Great Lakes area although they could become important in the future. Likewise, digestion processes involving use of acids, alkalies or enzymes are of little importance in the Midwest.

A number of newer rendering processes that could be used for fish have been described (2). These are in various stages of development. The waste disposal problems from their possible use are not well documented. One of them, the Carver-Greenfield process, has been stimulated in its development by the "paunch manure" disposal problems existing in the meat packing industry. Some of these processes are listed below:

- Pavia process
- Titan process
- Harberger Eisen and Brouzewerke process
- Kingan continuous rendering process
- Chayen-Sharples process

DeLaval process
Carver-Greenfield process
Marsh process
Battelle-National Renderer's Association process
U. S. Bureau of Commercial Fisheries Solvent
  Extraction Process for preparation of FPC

WET RENDERING PROCESS—WASTES

A flow sheet for wet rendering of sardine wastes is given in FOOD INDUSTRIES as part of an article discussing the recovery of by-products from fish wastes (3); further discussions of this process are given elsewhere in the literature (4,5,8). Rendering of alewives in the Great Lakes area is carried out in wet rendering plants of essentially identical design to that shown for sardine wastes in FOOD INDUSTRIES. A generalized version of a flow sheet for wet rendering of alewives and similar fishes taken from the Great Lakes is given in Figure 1.

Alewives are harvested from the Great Lakes and brought by boat to a rendering plant. W-1 is the water that accumulates in the holds of the boats as well as water used to clean the boats at the dock.

The fish are then transferred to a collection floor either by pumping or by mechanical conveyors. The quantity of fish can be determined at this site by weight or volume measurements. W-2 originates here. It is a mixture of fish scraps, scales, blood and water. If the fish are pumped from the boats to this site, the water used to fluidize the fish is screened out or drains off during the measuring operations.

Next the fish are transferred by a screw conveyor to a direct steam cooker which operates at essentially atmospheric pressure. Wastes from this operation are limited to leakage from the screw conveyor and to washup water (W-6).

From the cooker the fish pass to horizontal screw presses which separate liquid and solid fractions. The liquid is called press liquor, the solid is called press cake.

Press cake is conveyed to a direct fired, kiln type, rotary drier which removes water to produce a fish meal containing about 8% moisture. Exhaust gases (W-3) from this drier contain some fish meal dust and odors. These gases are vented directly to the atmosphere or are treated to remove dust and odors depending upon the local situation. The dried fish meal is next either sold directly or powdered in a hammer mill, if required. When a hammer mill is used, fine dust and some odors can issue from the cyclone separator that is used to collect powdered meal from the mill (W-4).

Press liquor is a mixture of water soluble constituents of the fish together with the fish oil and fine particles of fish tissue. Larger particles are removed on vibrating screens and then added to the wet press cake. Screened press liquor is pumped to a centrifuge.

This centrifuge discharges two streams, sludge and clarified press liquor.

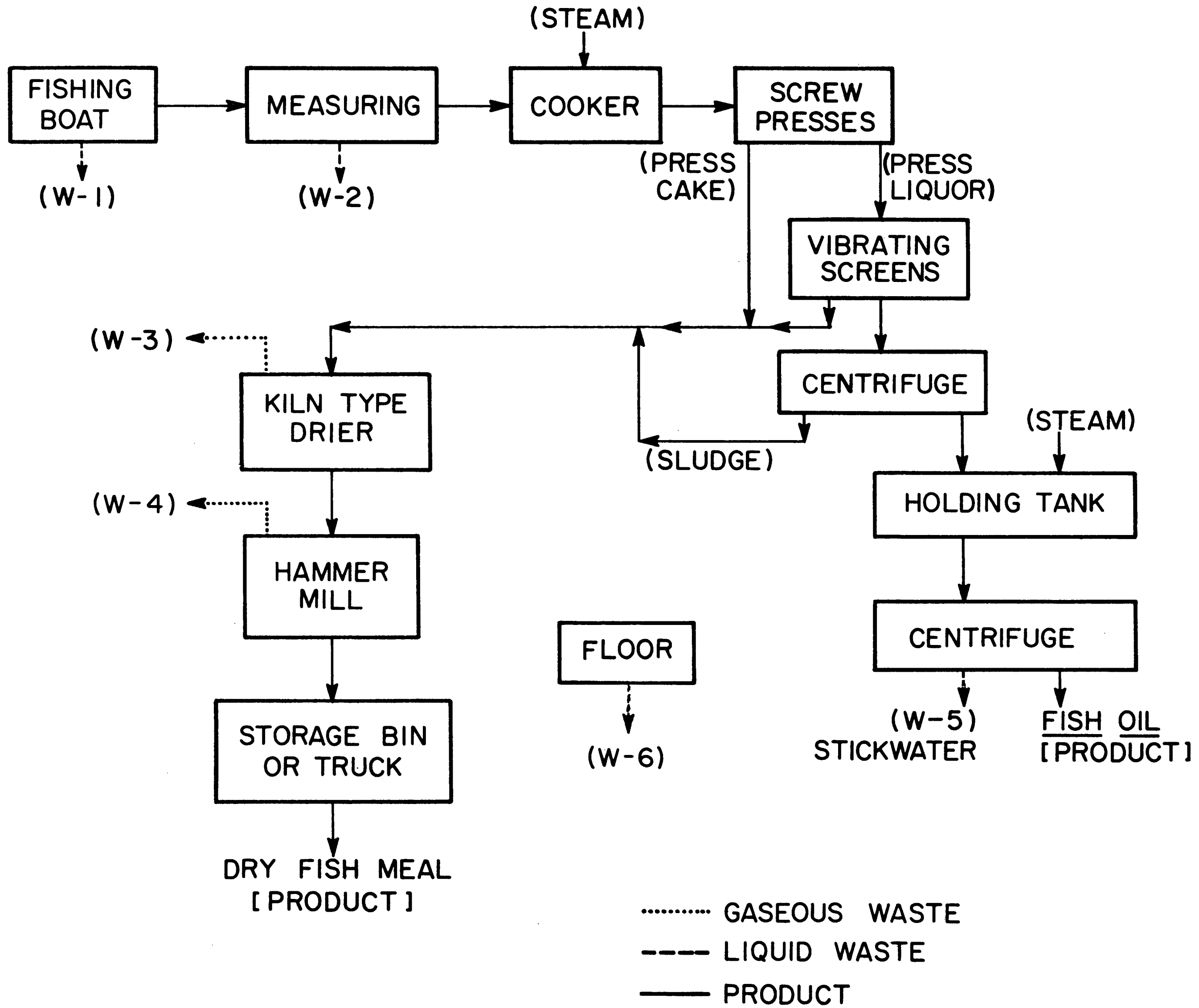


Figure 1. Flow diagram. Alewife rendering plant using the wet rendering process.

The sludge is added to the wet press cake for drying as part of the fish meal. The clarified press liquor is heated and then passed through an oil centrifuge.

Two streams issue from the oil centrifuges, these are fish oil, and stickwater (W-5). The fish oil is ready for shipment as a product, the stickwater constitutes a strong waste or a source of valuable products depending upon market conditions. Actually, stickwater is the most important waste developed by wet rendering alewives. This waste must be either eliminated or treated in such a way as to be acceptable in a receiving body of natural water or in a sewerage system. Some idea of the magnitude of the problem can be obtained by relating the BOD of stickwater to that of city sewage.

The 5-day BOD of stickwater can be obtained by calculations based upon analyses or from the literature (4). Using an average value of 47,000 ppm for the 5-day BOD, 1800 gallons of stickwater per 15 tons of fish processed and a population equivalent of 0.17 lb of 5-day BOD (6) the following calculation indicates the size of a city to which a 15-ton per hour fish reduction plant of the wet rendering kind can be related:

$$1800 \frac{\text{gal}}{\text{hr}} \times 24 \frac{\text{hr}}{\text{day}} \times 8.5 \frac{\text{lb}}{\text{gal}} \times \frac{47{,}000}{1{,}000{,}000} \times \frac{1}{0.17} \frac{\text{people-day}}{\text{lb BOD}} = 101{,}500 \text{ people}$$

Thus, a 15-ton per hour fish rendering plant, using the wet rendering process, can produce stickwater having a water polluting capacity equivalent to that of a city of over 100,000 people.

It is reported that the BOD of stickwater represents more than 90% of the pollutional load generated from the wet rendering of menhaden (4). In that same report it is pointed out that treatment of the remaining 10% was best accomplished by reducing the volumes of these remaining wastes to a minimum and then evaporating them along with the stickwater. The authors indicate that these procedures essentially eliminated water pollution problems previously existing at menhaden fish oil and meal processing plants in the State of Virginia.

DISPOSAL OF STICKWATER

The best waste treatment processes eliminate wastes entirely. This can sometimes be done by converting wastes into profitable by-products. Fortunately, stickwater contains many substances that are desirable supplements in fish meal that is sold for chicken or animal feeds (1,3,4,7). Therefore, concentrated stickwater can be added to partially dried fish meal, the drying process completed, and a fortified fish meal obtained. This fortified meal is known as "full meal" or as "whole meal" (1). Concentrated stickwater may also be sold as "condensed fish solubles" in some markets (1,3,7).

PROCESSES FOR CONCENTRATING STICKWATER

Theoretically a number of separation processes could be used to concentrate the solids in stickwater; among such processes are evaporation, freeze-concentration, and reverse osmosis. At present, the only practical concentration technique appears to be evaporation.

There are a number of evaporation processes that have either been used, tested or suggested for fish stickwater. The most widely mentioned in the literature is multiple effect evaporation (1,3,4). Both submerged combustion and submerged evaporation have apparently been used on a small scale (9). A patent exists for a special apparatus called a Vincent evaporator (12,13). Drum drying is also a possibility.

Multiple effect evaporators are steam heated and operate under vacuum. Because of their design, more than 1 lb of water can be evaporated from the stickwater per lb of heating steam applied. Submerged combustion, submerged evaporation and Vincent evaporators are direct fired. This means that heat present in combustion gases from gas or oil burners is used directly to evaporate the water. Drum driers require steam at relatively high pressure. They are simple to use and reliable. However, their steam economy is low, i.e., they evaporate less than a lb of water from stickwater per lb of steam used. They also present some expensive maintenance problems.

As previously stated in this report, the best method for treating a waste is to eliminate it. This can be done by producing a profitable product from it or by using an alternative process that does not develop it. With the first of these objectives in mind, a preliminary process design and cost estimate for triple effect evaporation of stickwater from alewife rendering wastes was prepared. Tentative design and cost estimates for concentrating such stickwater by submerged evaporation and a proposed spray evaporation process were also developed. It must be emphasized that these three process designs are preliminary in nature and that the cost estimates were based upon data from the literature or upon assumptions. They are intended only as initial estimates for comparing the probable feasibility of the various kinds of evaporation methods considered.

A. MULTIPLE EFFECT EVAPORATION

In a number of instances, multiple effect evaporation of fish stickwater has successfully eliminated it as a pollution problem (4). This type of evaporator can produce high quality fish solubles. It is best adapted to plants where production of stickwater occurs in large volume on a continuous basis. On the other hand, multiple effect evaporators are expensive, they require intelligent operation and need both steam and cooling water. They should be operated continuously because it takes quite a while to restore them to operation each time they are shut down. Also they are expensive initially and overhead charges continue whether or not they are operating. Unfortunately, alewife rendering plants don't usually operate continuously but rather must depend upon a fish catch that is both seasonal and erratic when in season. Therefore, the economic advantage that can accrue from use of multiple effect evaporators is likely to be difficult to achieve at most alewife rendering plants in the Midwest.

In addition, multiple effect evaporators have fairly complicated auxiliary equipment such as vacuum apparatus, feed pumps, barometric legs, etc. These require expert operation and maintenance. Furthermore, the heating tubes periodically accumulate scale that lowers efficiency and requires shutting the plant down for cleaning. It is reported (3) that deposition of this scale can be reduced by acid treatment of the stickwater before evaporation. Acid treatment also is reported to precipitate albuminoid solids and reduce viscosity of the stickwater. This treatment apparently allows evaporation to proceed to 50% solids content in the product rather than to 30 or 35% solids without acidification.

It should also be noted that improper operation of multiple effect evaporators can cause water pollution problems. Condensed steam from each effect will normally contain volatile substances removed by vacuum evaporation. Foaming and entrainment can also occur under adverse operating conditions. When this happens the condensed steam can have extremely high BOD values. Again the need for trained, skilled operators is evident. Also, when the evaporators are shut down for repair, the stickwater in the evaporators must be removed. It can be pumped to storage vessels if they are available; it obviously cannot be discharged into a stream without polluting it. Odor problems should be minimum with proper operation of multiple effect evaporators (1).

Calculations based upon data in the literature (3) suggest that between 110 and 206 gallons of stickwater are developed by wet rendering of sardines. It is recognized that incidental water can accumulate as part of the stickwater during actual operations and that the composition of stickwater can vary widely. A range between 5 and 8% solids is common (1). The amounts of stickwater produced per ton of sardines, as quoted above, are calculated below. Between 2250 and 2625 lb of condensed fish solubles are reported to be produced per 15 tons of sardines during wet rendering (3). Fish solubles contain about 50% water, thus:

$$2625 \times 0.5 \times \frac{1}{.05} \times \frac{1}{8.5} \times \frac{1}{15} = 206 \text{ gal/ton of fish}$$

$$\frac{\text{lb of solubles}}{} \times \text{fraction of solids in solubles} \times \frac{\text{lb stickwater}}{\text{lb solids}} \times \frac{\text{gal stickwater}}{\text{lb stickwater}} \times \frac{1}{\text{tons of fish}}$$

or

$$2250 \times 0.5 \times \frac{1}{.08} \times \frac{1}{8.5} \times \frac{1}{15} = 110 \text{ gal/ton of fish}$$

It is evident that the difference between 110 and 206 gallons of stickwater per ton of fish is large, particularly since the size of evaporators needed is directly related to these volumes. When designing evaporators upon which to base our conclusions, we deliberately chose a high value of 235 gallons of stickwater per ton of fish in order to develop a conservative design. This latter value is based upon 25% solids in the fish, 20% loss of solids during pressing, and 5% solids in this stickwater. Hence the costs for evaporating stickwater presented later in this report are likely to be in the high range.

It is evident that information regarding the physical properties of stickwater from alewife rendering would be useful for both the design and operation of evaporators. Such information should at least include data on heat transfer coefficients, viscosity, and scaling tendencies. Laboratory studies for obtaining these data should be undertaken if evaporator systems to be based at alewife rendering plants are to be efficiently designed and operated in the Midwest. Accurate knowledge of the volume and composition of stickwater produced per ton of fish rendered is also required since the size of evaporators is directly related to this factor.

Using data from the literature together with assumed values for heat transfer coefficients, operating conditions, cost parameters, etc., N. E. Lake and R. E. Scherr designed a triple-effect evaporator system for concentrating fish stickwater. This design was made as part of the present study. It is entitled "Production of Dried Solubles from Alewife Stickwater by Triple Effect Evaporation." Their complete report is attached to the present report as Appendix I. They offer cost estimates for triple-effect evaporation systems designed to accompany various sized fish rendering plants and to produce concentrated stickwater with various solids concentrations. Based upon their calculations, a triple-effect evaporation system for a 10-ton per hour fish rendering plant would have an installed cost of $443,000 and a yearly operating cost of $142,900. Such a plant would produce dried solubles at 2.45¢/lb. Costs of evaporators for fish rendering plants of other sizes are also included. The cost of dried solubles is plotted as a function of the feed rate in Figure 2. Feed rate refers to the size of the fish reduction plant for which a companion evaporation system was sized. It is fortunate that our computations indicated that one ton of stickwater was formed by wet rendering of one ton of fish. The "feed rate" in this instance then could equally well refer to tons of stickwater per hour.

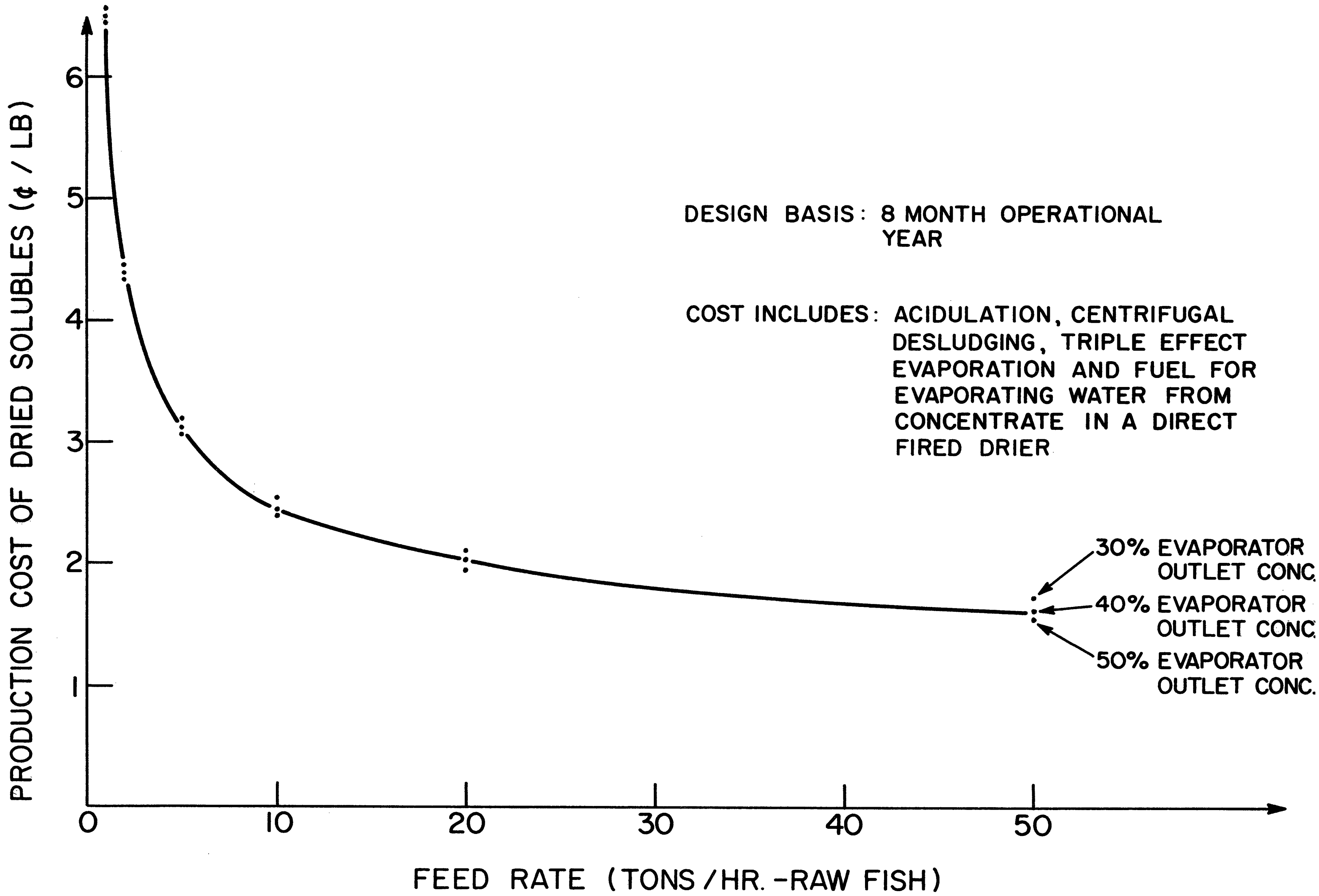


Figure 2. Production cost of dried solubles from stickwater by triple-effect evaporation.

Based upon these design data, Lake and Scherr indicate in Figure 2 that the minimum sized plant for profitable production of concentrated fish solubles would be done with a feed rate of approximately 2 tons of fish per hour. This is based upon incorporating concentrated fish solubles into fish meal when such meal sells for about 6¢/lb (14). Actually it will be observed in Figure 2 that a plant processing between 10 and 20 tons per hour of raw fish would include a triple-effect evaporation process capable of making fish solubles at a cost of approximately 2¢/lb. It should be emphasized that the processing rate, expressed in tons of fish per hour, also presumes an 8-month operating year and a 24-hour operating day for the triple-effect evaporators.

While it is probable that multiple effect evaporators could be very desirable for concentrating fish stickwater in many circumstances, the deficiencies of such equipment enumerated above indicate that the other types of evaporators should also be evaluated for this purpose.

B. SUBMERGED EVAPORATION

There are two kinds of submerged evaporators. Carpenter (9) points out that submerged combustion units operate with the flame submerged in a pipe below the liquid surface. Submerged evaporators are designed to pass only hot gases rather than a flame through the evaporating liquid. The burner in submerged evaporators is located above the liquid, thus it is not so likely to burn organic material. Both submerged combustion and submerged evaporation units have been tested for concentrating fish stickwater. Carpenter (9) indicates that submerged evaporation can be used successfully for this purpose. Submerged combustion units are reported to be reasonably successful in a South American installation (11) but there is some question regarding the quality of fish solubles produced. Gray or black particles apparently develop in the concentrate. This could be due to local burning. Both of these kinds of evaporators can be started and stopped quickly. They would thus appear well adapted to the intermittent operation schedules of alewife rendering plants. The equipment involved is relatively simple and should be inexpensive. In general this equipment is simply a burner, suitable controls and an open tank to contain the evaporating stickwater.

Steam from submerged combustion or submerged evaporation units normally discharges to the atmosphere. This would almost certainly produce obnoxious odors. The steam could be condensed in a spray of water in a suitable tower. It is probable that this would not reduce the odors to acceptable levels, so before advocating use of such evaporators for plant applications, considerable pilot plant study of possible odor problems is indicated. In addition, submerged combustion units could present and explosion hazard if improperly designed or operated (10). It would seem that the explosion hazard would particularly apply to gas fired units. It might not be involved with oil fired equipment. This too should be evaluated in pilot installations.

Submerged combustion and submerged evaporation devices evaporate less than one pound of water per 1000 Btu's which is the approximate latent heat in a pound of steam. Attempts to "stage" submerged combustion evaporators have not been very successful although this procedure is theoretically possible (10).

There are yet other items that should be evaluated before advocating the use of submerged combustion or evaporation equipment. Circulation of the evaporating fluid in these devices is accomplished largely by the air-lift characteristics of the combustion gases rising through the viscous liquid. This is not a positive action such as is supplied by most pumps. It is stated (11) that about 30 to 35% solids is the maximum concentration attainable with the submerged combustion type evaporator because of this viscosity problem. Impeded circulation could lead to burning of the product. One more problem seems likely, that of foaming. It is reported that the high temperature of the gases tends to keep foaming under control (9). This certainly would need confirmation in a pilot plant.

With these ideas in mind, R. C. Scherr prepared a preliminary cost study for a submerged evaporation system for fish stickwater. His design is based upon Carpenter's data (9), and is included with the present report as Appendix II. It will be noted that Scherr's design is based on a 2-ton per hour evaporation plant. Again for this design, one ton of stickwater was assumed to be formed during the wet rendering of one ton of fish. This is the same volume basis used in the calculations in Appendix I for the triple-effect evaporator. For the cost calculation, both Appendices I and II are based on a stickwater containing 5% solids.

Mr. Scherr's calculations indicate that the initial investment for submerged combustion evaporation is approximately half that for triple-effect evaporation. His data also indicate a somewhat lower manufacturing cost for dried solubles produced by submerged evaporation. However, his cost for finish drying of the solubles appears to be about 0.2¢/lb low. Using data for Appendices I and II it is possible to compare the cost of dried solubles produced by triple-effect and submerged evaporation. For example, in Figure 2 the cost for dried solubles is given as 2.45¢/lb by triple-effect evaporation at a feed rate of 10 tons per hr for raw rish. A comparable cost for dried solubles produced by submerged evaporation is approximately 1.95¢/lb.

It should be emphasized that triple-effect evaporation is a standard, tested process for stickwater concentration; while submerged evaporation is still at the pilot plant stage. Nevertheless, the slight economic advantage that appears to exist for submerged evaporation together with the lower investment cost and ease of operation, make it necessary to consider submerged evaporation as a potentially valuable process for concentrating fish stickwater.

C. VINCENT EVAPORATOR

The third type of equipment named above is of the spray drier variety. One apparatus of this kind is the Vincent evaporator. The patents (12,13) indicate that evaporation is carried out by spraying the stickwater into a chamber countercurrent to the flow of the combustion gases although countercurrent flow is said to exist in an inner zone. Under these conditions high heat transfer rates are attained by direct contact between the hot gases and drops of liquid. This, of course, is the basic concept involved in spray drying. It is probable that very rapid concentration of stickwater could occur in this equipment. It should also be possible to turn such an apparatus on and off almost at will which would make it particularly adaptable to use in small alewife rendering plants.

Again there are probable and actual problems involved in the use of a spray drier type of appratus for this application. It seems possible that the stickwater concentrate could develop a gray color like that observed with submerged combustion because present equipment of this kind mixes hot gases with drops of stickwater in a chamber under countercurrent flow conditions (13). The burning of product is not uncommon in countercurrent flow, food driers (16). This occurs because the hottest gases directly contact the driest food. In parallel flow driers, the hottest gases contact wet foods which reduces this burning effect. For this reason, counter flow evaporation should be avoided.

In addition to the possibility of developing a darkened product, a potential explosion hazard seems to exist in operating most direct heated evaporators. This is particularly true when gas is used for fuel. It should be possible to control this hazard by suitable design and by training equipment operators to expect and avoid the problem.

Also, with direct heated evaporators the fuel must be selected to be sure that its combustion products do not contain toxic or damaging substances that could be absorbed into the stickwater since the concentrate is to be used for animal or poultry feed.

D. SPRAY CONCENTRATOR (Proposed)

Consideration of the good and bad features of the various devices so far discussed leads to the suggestion of yet another possible evaporation technique for alewife stickwater produced in Midwest rendering plants. The best evaporator for this purpose should have as many of the following characteristics as possible:

low initial cost
low maintenance charges
low operating costs

cheap fuel
high fuel economy
quick to start and stop
produce high quality, concentrated fish solubles
develop no air or water pollution problems

It is proposed that a new device be tested for spray concentrating stickwater. This apparatus would utilize an important feature of spray drying (15), namely intimate mixing of drops of stickwater and hot gases. The Vincent evaporator also utilizes this principle. In the proposed device, the flow of hot combustion gases at about 1400°F would be parallel to the drops of stickwater. Parallel flow is likely to result in less damage to any of the drops of stickwater that may over-concentrate. This gentler characteristic of parallel versus countercurrent flow is recognized as a desirable feature of food driers (16). In spite of the gentler concentrating action expected with parallel flow the rate of evaporation should be faster than with countercurrent flow. There is, however, a degree of similarity between the proposed spray concentrator, standard spray driers, and the Vincent evaporator.

A preliminary sketch for a pilot unit to test the proposed spray concentrator is shown in Figure 3. Based upon tentative calculations a pilot unit of this kind for spray concentrating 1 ton per hour of fish stickwater from 5% to 50% solids would cost approximatly $16,500.

It is evident that much yet needs to be known before recommending any of these four evaporators as being the best one for concentrating the stickwater produced by wet rendering of alewives. Perhaps enough is known about triple-effect evaporation to be reasonably confident that a particular unit would operate according to designed calculations. If not, heat transfer coefficients, etc., that are necessary to such a design could be relatively easily obtained by laboratory tests. However the operating characteristics and design data are not well known for the submerged evaporator or spray evaporator; they may be fairly well documented for the Vincent evaporator although data available in the literature does not appear to be specific for alewife wastes.

With the above observations in mind it is evident that pilot testing of all four evaporators, under comparable conditions, would be a useful undertaking. The results could be important to the fish rendering industry. In addition such tests could have theoretical interest to chemical engineers and practical value wherever the disposal of strong wastes is a problem. Such wastes are not uncommon. For example citric peel liquors (17), antibiotic fermentation beers (18), and whiskey stillage (19) have been concentrated as preliminary steps to their use or disposal. Thus, the data obtained from pilot plant evaporation studies of fish stickwater could have rather wide applicability.

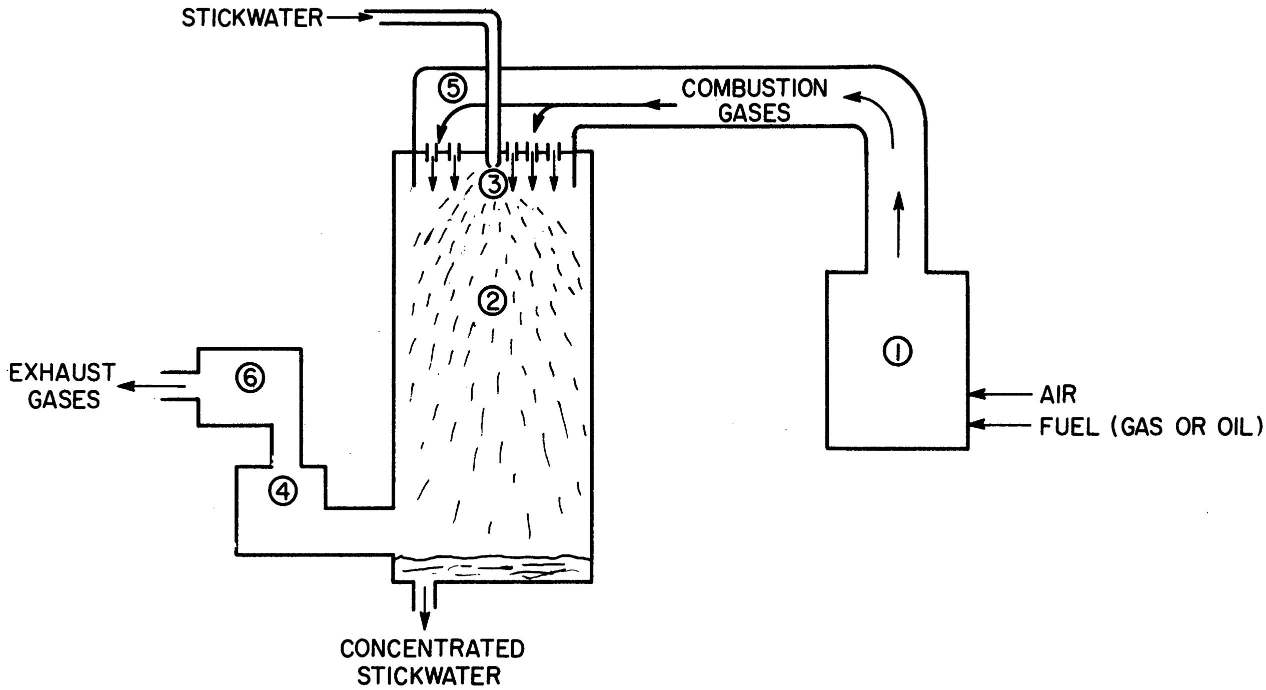


Figure 3. Suggested research pilot test unit for spray concentrating of fish stickwater.

Key:

1. Burner
2. Spray concentration chamber (large pipe or tank)
3. Nozzle or disc
4. Demister and cyclone separator to remove fine drops of concentrated stickwater from exhaust gases.
5. Plenum chamber to direct the combustion gases downward in parallel flow with drops of stickwater generated at (3).
6. Exhaust blower

SUMMARY AND CONCLUSIONS

Wet rendering of fish produces strong wastes. Stickwater is the most troublesome of these. Calculations indicate that stickwater from a 15-ton per hour wet rendering plant can have a BOD equivalent to the sewage from a city of over 100,000 people. Fortunately the solids in stickwater have market value. Therefore stickwater should not be considered a waste but rather an intermediate product. Elimination of a waste by developing a profitable product from it is an ideal treatment process. Reports in the literature indicate that stickwaters from wet rendering of sardine scraps and of menhaden have been profitably converted into concentrated fish solubles. These were sold as such or were added to fish meal. Both the sardine and menhaden operations appear to have been conducted in sufficiently big plants to justify the rather large capital investment and overhead charges needed for multiple effect evaporators. Unfortunately, alewife rendering plants in the Midwest are small. The initial investment and overhead charges seem too high to interest plant owners in using multiple effect evaporators at the present time.

Other methods have been suggested for evaporating stickwater that might be cheaper and therefore easier to justify. Unfortunately these methods have not had wide application anywhere, particularly not in the Midwest. Such alternate evaporation methods include submerged combustion, submerged evaporation and the Vincent evaporation process. These three methods employ direct heating.

A fourth variety of direct heated evaporator is proposed for study. This evaporator is called a spray concentrator. Its design is similar in many ways to the spray drying process (15) as is the Vincent evaporator. One difference between the proposed spray concentrator and the Vincent evaporator lies in the method of contacting drops of stickwater and the combustion gases. A Vincent patent specifies countercurrent flow of hot gases and drops of stickwater; the proposed spray concentrator would necessarily operate in the opposite manner, that is, by parallel flow or hot gases and drops of stickwater.

One inescapable fact is evident. The volume and particularly the strength of wastes caused by wet rendering of fish are so large that relatively small plants can cause major pollution problems. If fish rendering is to survive as an industry in the Midwest, the waste treatment problems must be economically solved. This can come about by use of rendering processes that do not develop waste problems or by adequately solving waste problems for the present rendering plants. Suggestions are offered to aid in reducing or eliminating these problems for wet rendering plants. It must be emphasized that the suggestions offered in this report for evaporating stickwater require testing in suitable pilot plants before they can be recommended for use at alewife rendering plants in the Midwest.

Such testing should preferably be done by cooperative efforts between the fishing industry and competent waste treatment experts.

LITERATURE CITED

1. Stansby, M. E. 1963. Industrial fishery technology. Reinhold Pub. Co., New York. Lib. Cong. Cat. No. 63-18354.

2. Wilder, O.H.M. 1962. New processes and developments in the rendering industry. Amer. Meat Inst. Foundation, 939 East 57th St., Chicago, Ill. Circular No. 72 (Sept.).

3. Anon. 1950. "Recovering by-products from fish waste." Food Industries, 22(2), 54-57, 96-99.

4. Paessler, A. H., and R. V. Davis. 1956. Waste waters from menhaden fish oil and meal processing plants. Proc. 11th Industrial Waste Conference, Purdue, Univ., Lafayette, Ind., pp. 371-388.

5. Nemerow, N. L. 1963. Theories and practices of industrial waste treatment. Addison Wesley Pub. Co., Inc. Lib. Cong. Cat. No. 62-14062, pp. 362-364.

6. Babbitt, H. E., and E. R. Baumann. 1952. Sewerage and sewage treatment. John Wiley and Sons, Inc. Lib. Cong. Cat. No. 58-13453, p. 359.

7. Sanford, F. B., and C. F. Lee. 1960. U. S. fish reduction industry. Commercial Fisheries T.L. 14 published by the Branch of Technology Bureau of Commercial Fisheries, U. S. Dept. of the Interior.

8. Butler, C. 1949. Fish reduction processes. Fishery Leaflet 126, Fish and Wildlife Service of the U. S. Dept. of the Interior.

9. Carpenter, G. A. 1958. Submerged evaporation and its application to fish stickwater recovery. Chemical and Process Eng., 39, 425-428.

10. Swindin, N. 1949. Recent developments in submerged combustion. Trans. Inst. of Chem. Engrs., 27, 209-221.

11. Personal communication.

12. Vincent, D. B. 1952. Process for treating fish press fluids. Patent No. 2,595,180 United States Patent Office, April 29, 1952.

13. Vincent, D. B. 1958. Process of evaporating moisture from syrup-forming solutions. Patent No. 2,818,917 United States Patent Office, January 7, 1958.

14. *Oil Paint and Drug Reporter*, March 4, 1968.

15. Perry, J. H. 1963. *Perry's Chemical Engineers Handbook*. McGraw-Hill Book Company, Inc., New York, Fourth Ed. Lib. Cong. Cat. No. 61-13168.

16. Van Arsdel, W. B. 1951. Tunnel and truck dehydrators, as used for dehydrating vegetables. AIC-308, Western Regional Research Laboratory, Albany, Calif. Bur. of Agr. and Ind. Chem., U.S.D.A., May 1951.

17. Burdick, E. M., *et al*. 1949. Application of submerged combustion to processing of citrus waste products. *Chem. Eng. Prog.*, *45*(9), 539-544.

18. Edmonson, K. H. 1954. Disposal of antibiotic spent beers by triple-effect evaporation. *Proc. 8th Ind. Waste Conf.*, Purdue Univ., Lafayette, Ind., Engr. Ext. Ser. No. 83, 46.

19. Boruff, C. S. 1952. Grain distilleries. *Ind. Eng. Chem.*, *44*, 491-493.

APPENDIX I

PRODUCTION OF DRIED SOLUBLES FROM ALEWIFE STICKWATER BY TRIPLE-EFFECT EVAPORATION

by N. E. Lake and R. C. Scherr

Summary

Based upon information from the open literature it is evident that valuable fish solids can be recovered from "stickwater" discharged as waste from fish rendering plants. Our calculations suggest that alewife rendering plants with capacities greater than one to two tons per hour should be able to profitably concentrate "stickwater" if the evaporators operate continuously eight months out of the year. The concentrate would be incorporated with partly dried fish-meal and the mixture then finish dried. It is reported that this process is being successfully used to eliminate "stickwater" wastes from other fish rendering plants. Obviously, eliminating the waste is the best waste disposal system.

Only triple-effect evaporation has been considered in this report. Other evaporation processes seem to offer advantages for evaporation of "stickwater." Submerged combustion and spray evaporation, for example, should be investigated in this connection.

Introduction

Liquid wastes from the fish processing industries can cause undesirable waste disposal problems. In particular, small rendering plants in the Great Lakes region are said to be causing serious pollution problems. The pollutant in question is a high protein waste known as "stickwater." This waste has a high BOD which makes conventional treatment almost impossible. Even a small plant has a population equivalent of several thousand. Direct return to the lakes can cause serious pollution.

Several alternatives are available to the investigator. Among these are the following:

1. Development of improved methods for treating the waste.

2. Investigation of alternate disposal methods.

3. Development of a supplementary process for removal of the solids from "stickwater."

4. Alteration of the present rendering process to eliminate the waste.

5. Finding new products to be made from the high protein fish waste.

The third point deserves special consideration since the East Coast menhaden rendering industry has already eliminated most of their waste in this manner. These plants have installed triple-effect evaporators to concentrate the "stickwater" to about 50% solids. The concentrated product is then mixed with the moist meal from the presses and dried on a direct fired rotary drier (1). The final product is then referred to as "full meal." Alternatively, the product may be sold on the market as "fish solubles."

Since the menhaden rendering plants on the East Coast are larger than the alewife rendering plants of the Great Lakes region and since they process a different fish, it is logical to expect the profitability pictures to be different. In addition, there must be a minimum sized alewife rendering plants for profitable operation.

It is the object of this particular study to determine the throughput of that minimum sized plant. Important variables influencing the profitability will be determined. Where uncertainties exist in these variables, areas for further study will become evident.

Process Description

The process described below is intended for addition to an existing rendering plant. Therefore, the rendering plant, itself, will not be described.

The "stickwater" is first fed to an acidulation tank where sulfuric acid is added in sufficient quantity to coagulate colloidal proteins. Approximately 9-1/2 pounds of acid are required per ton of "stickwater." The coagulated solids are removed by centrifugation and added to the fish meal (2). The acidulation step coupled with the centriguation is needed to reduce scaling in the evaporators and to eliminate a "fishy" smell in the product (3). Evaporators usually can be operated at least one month before they need cleaning if the coagulation pretreatment is employed (4).

The remaining liquid is stored temporarily in the evaporator feed and emergency storage tank. This tank is excessively large in order to accommodate two hours of feed in case the evaporator or other parts of the process malfunction.

During shutdowns, the acidulated and centrifuged "stickwater" may be stored for as long as two or three weeks before it begins to deteriorate (5). Since any liquid held in the third effect in the evaporators is at the final concentration, it may be dried in the drier or sold as "fish solubles." However, the liquor in the first two effects of the evaporator system must be stored until the next start-up period. Therefore, the evaporator feed and emergency storage tank is large enough to easily accommodate the evaporator hold-up of the first two effects.

The feed from this tank to the first effect of the triple-effect forward feed evaporator system is assumed to be 180°F and 5% solids concentration (6). Forward feed evaporation is chosen to avoid scorching of the product. However, highly viscous products often require backward feed evaporation. If laboratory data indicate that the product is highly viscous, backward feed should be employed. However, even if lab data indicate that backward feed is appropriate, the change in estimated cost of the evaporator system should be within the range of uncertainty created by very sketchy heat transfer coefficient information.

Low pressure steam (15 psig) is sufficient to heat the first effect liquor to a temperature of about 237°F. The cost of generating the low pressure steam is based on a small package boiler system. Hopefully, there will be enough capacity in present boilers to meet this additional requirement. If there is not, the installed cost of the plant (as reported in the economic analysis) must be increased by the amount of a package boiler unit.

The final effect of the evaporator system will produce a product of 50% solids concentration at 120°F. This concentrate or "fish solubles" may be solid or added to meal from the rendering plant. In the suggested design, the concentrate is added to the moist meal and dried in the existing direct fired rotary drier. It is assumed that existing equipment can handle the finish drying step when additional fuel oil is supplied.

Figure A-1 shows the equipment layout. Table I lists each piece of equipment and its respective size. Flow rates and equipment sizes are given for an evaporation plant to supplement a 10-ton per hour rendering plant and produce a 50% solubles concentration. Several other sized plants were also designed. In addition, a final solubles concentration of 30% and 40% solids was specified for each size. The results of these variations are presented in the economic analysis section.

Gravity flow is anticipated in several instances. It is assumed that the railroad spur will be located above the level of the acidulation tank so that no expensive acid pumps are required. The centrifuge is also located above the level of the evaporator feed tank for gravity flow of the supernatant liquid into the evaporator feed tank.

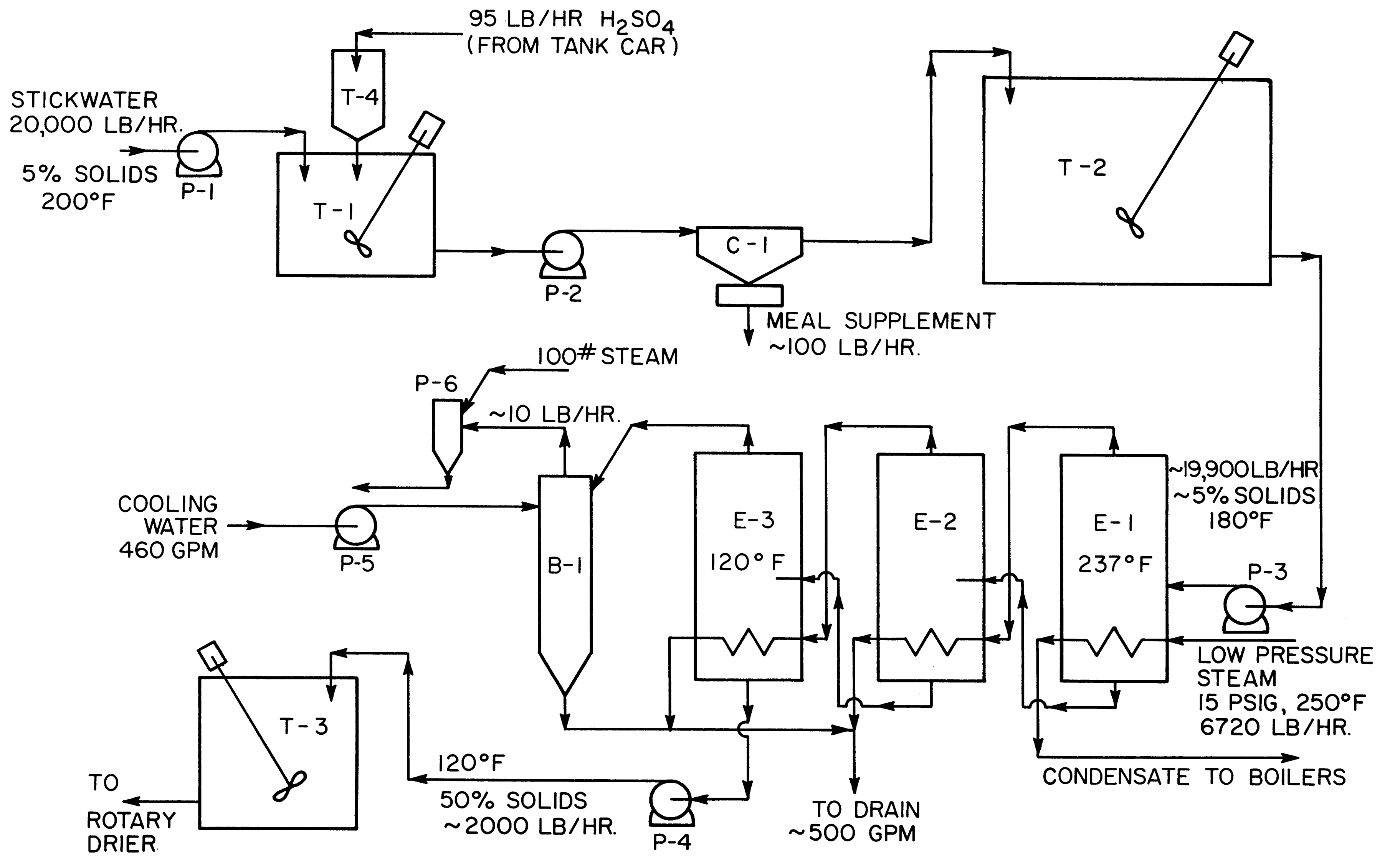


Fig. A-1. Process flow sheet. Stickwater evaporation plant to supplement a 10-ton/hr rendering plant.

TABLE I

EQUIPMENT SCHEDULE

(for 10 tons per hour feed to the rendering plant and 50% solubles concentration)

E-1	Evaporator (first stage)	vertical tube, steel, 1520 ft^2 heat transfer area
E-2	Evaporator (second stage)	same as E-1
E-3	Evaporator (third stage)	same as E-1
C-1	Centrifuge	steel, 3500 rpm
B-1	Barometric condenser	steel, 460 gpm cooling H_2O
T-1	Acidulation tank	1250 gal, steel, covered agitated
T-2	Evaporator feed and emergency storage tank	5000 gal, steel, covered, agitated
T-3	Solubles storage tank	1000 gal, steel, covered, agitated
T-4	Acid drip tank	15 gal, glass lined, covered
P-1	Feed pump	50 gpm, centrifugal, iron
P-2	Centrifuge feed pump	same as P-1
P-3	Evaporator feed pump	same as P-1
P-4	Solubles pump	10 gpm, centrifugal, iron
P-5	Cooling water pump	460 gpm, centrifugal, iron
P-6	Steam jet ejector	noncondensing, 10 lb/hr, 50 mm Hg

Design Basis

In designing this process it was discovered that a minimal amount of technical data concerning various aspects of similar processes are available. Because of this and because of the need to specify various operational conditions several assumptions were made. These assumptions are listed, with some justifications, below:

1. Operation will be 24 hours per day for an eight-month season—continuous operation is needed for efficient triple-effect evaporation.

2. High pressure steam will be available to run a steam jet ejector. The amount will be negligible since intermittent operation is sufficient.

3. Carbon steel will be sufficient for construction except for the acid drip tank.

4. The evaporator feed will be at 180°F and the "stickwater" from the rendering process will be at 200°F.

5. The pressure in the third effect will be 3 in. Hg.

6. Boiling point rise will be negligible due to high molecular weight of the protein solids. Assume that it is 4°F at 50% solids concentration.

7. The overall heat transfer coefficients will be 300, 100, and 50 Btu/hr-°F ft^2 for effects 1, 2, and 3, respectively.

8. The input fish contain 25% solids, the stickwater contains 5% solids (7) and the fish solubles contain 50%, 40%, or 30% solids depending on the particular design.

9. Each evaporator has equal heat transfer data.

10. Low pressure steam will either be available for evaporation or a package boiler unit will be provided.

11. The coagulation of colloidal protein may be accomplished with a 30-min retention time in the acidulation tank (8).

12. Although the specifications for the centrifuge are not well defined, an estimate of price may be determined from roughly similar units in <u>Perry's Chemical Engineers Handbook</u>.

13. The direct fired rotary drier in use in the main plant will be adequate to finish dry the fish solubles. However, additional fuel oil is supplied.

14. a 55% thermal efficiency is assumed in the rotary drier (9).

15. A railroal spur is assumed to run to the plant for acid delivery.

16. The additional process is assumed to require the services of two additional men.

Economic Analysis

As mentioned earlier, the primary objective of this study is to determine the break-even point between the unprofitable and profitable addition to existing facilities. Therefore, the cost of each piece of equipment in the triple-effect evaporator system is represented by a cost equation. This equation may then be used to estimate equipment costs for any plant within a reasonable proximity to the one required for a 10-ton per hour rendering plant (10). This procedure is repeated for three solubles concentrations (30%, 40%, and 50% solids concentration) in order to compare their relative economics. In addition, six different plant sizes are specified and their basic costs determined.

Factors such as installation, instrumentation, insulation, piping, foundations, structures, electrical work, painting and cleanup, engineering fees, and contingencies are considered in order to determine the initial installed cost. Then yearly operating expenses are determined. These include depreciation on a ten-year payout basis, labor, utilities, maintenance, and raw materials. When the total of these expenses are balanced against the additional meal which is produced, a production cost of dried solubles may be determined. See Table II for these results. Note pages 21 and 22 of the calculation file for more details of the economic factors, equipment cost equations, and operational cost equations.

The production cost of dried solubles is plotted as a function of plant size and solubles concentration in Fig. A-2.

Fish meal from the menhaden industry on the East Coast sells for about 6¢/lb (14). If this is taken as an approximate price for alewife meal, one may easily determine that the break-even point occurs between one and two tons per hour. The uncertainties caused by the many assumptions discussed in the design basis indicate that this size is only approximately. However, there is no doubt that evaporation of the waste stream and recovery of the protein from it can be a profitable operation.

TABLE II

PRODUCTION COST FOR DRIED FISH SOLUBLES

(a) 1 ton/hr, raw fish feed rate*

Equiption		Cost Equation	Cost
Tanks		$67(F)^{.53}$	$ 3,764
Pumps		$280(F)^{.21}$	1,382
		$37(F)^{.38}$	665
Evaporators:	30% outlet	$812(F)^{.55}$	53,013
	40% outlet	$838(F)^{.55}$	54,804
	50% outlet	$850(F)^{.55}$	55,589
Barometric Condenser		$19(F)^{.55}$	1,243
Steam Ejector			600
Centrifuge		$97(F)^{.6}$	9,277

	30% Outlet	40% Outlet	50% Outlet
Base Cost (B.C.)	$ 69,944	$ 71,737	$ 72,520
Installed cost (I.C. = 1.75 B.C.)	122,000	126,000	127,000
Depreciation (10% I.C.)	12,200/yr	12,600/yr	12,700/yr
Labor	16,000	16,000	16,000
H_2O (.1212 F)	242	242	242
Electricity (1.0094 F)	2,017	2,018	2,018
Low Pressure Steam	1,796	1,890	1,936
Rotary Dryer Fuel Oil	2,200	1,416	944
Maintenance (4% I.C.)	2,798	2,868	2,901
H_2SO_4 (.461 F)	922	922	922
Yearly Operating Cost	$ 38,176	$ 37,957	$ 37,663
Production Cost of Dried Solubles	6.53¢/lb	6.50¢/lb	6.45¢/lb

*F = feed rate to rendering plant in pounds of raw fish per hour.

TABLE II (Continued)

(b) 2 tons/hr, raw fish feed rate*

Equipment		Cost Equation	Cost
Tanks		$67(F)^{.53}$	$ 5,435
Pumps		$280(F)^{.21}$	1,598
		$37(F)^{.38}$	865
Evaporators:	30% conc.	$812(F)^{.55}$	77,748
	40% conc.	$838(F)^{.55}$	80,237
	50% conc.	$850(F)^{.55}$	81,386
Barometric Condenser		$19(F)^{.55}$	1,819
Steam Ejector			600
Centrifuge		$97(F)^{.6}$	14,061

	30% Conc.	40% Conc.	50% Conc.
Base Cost	$101,216	$103,705	$104,854
Installed Cost	177,000	181,000	183,000
Depreciation	17,700/yr	18,100/yr	18,300/yr
Labor	16,000	16,000	16,000
H_2O	485	485	485
Electricity	4,037	4,037	4,037
Low Pressure Steam	3,592	3,780	3,872
Rotary Dryer Fuel Oil	4,400	2,832	1,888
Maintenance	4,065	4,164	4,210
H_2SO_4	1,844	1,844	1,844
Yearly Operating Cost	$ 52,123	$ 51,242	$ 50,636
Production Cost of Dried Solubles	4.46¢/lb	4.39¢/lb	4.34¢/lb

*F = feed rate to rendering plant in pounds of raw fish per hour.

TABLE II (Continued)

(c) 5 tons/hr, raw fish feed rate*

Equipment		Cost Equation	Cost
Tanks		$67(F)^{.53}$	$ 8,832
Pumps		$280(F)^{.21}$	1,937
		$37(F)^{.38}$	1,225
Evaporators:	30% conc.	$812(F)^{.55}$	128,693
	40% conc.	$838(F)^{.55}$	132,814
	50% conc.	$850(F)^{.55}$	134,716
Barometric Condenser		$19(F)^{.55}$	3,011
Steam Ejector			600
Centrifuge		$97(F)^{.6}$	24,365

	30% Outlet	40% Outlet	50% Outlet
Base Cost	$168,663	$172,784	$174,686
Installed Cost	295,000	302,000	306,000
Depreciation	29,500/yr	30,200/yr	30,600/yr
Labor	16,000	16,000	16,000
H_2O	1,212	1,212	1,212
Electricity	10,094	10,094	10,094
Low Pressure Steam	8,980	9,450	9,680
Rotary Dryer Fuel Oil	11,000	7,080	4,720
Maintenance	11,800	12,080	12,240
H_2SO_4	4,610	4,610	4,610
Yearly Operating Cost	$ 93,196	$ 90,726	$ 89,156
Production Cost of Dried Solubles	3.19¢/lb	3.11¢/lb	3.05¢/lb

*F = feed rate to rendering plant in pounds of raw fish per hour.

TABLE II (Continued)

(d) 10 tons/hr, raw fish feed rate*

Equipment		Cost Equation	Cost
Tanks		$67(F)^{.53}$	$ 12,753
Pumps		$280(F)^{.21}$	2,241
		$37(F)^{.38}$	1,594
Evaporators:	30% conc.	$812(F)^{.55}$	188,418
	40% conc.	$838(F)^{.55}$	194,451
	50% conc.	$850(F)^{.55}$	197,236
Barometric Condenser		$19(F)^{.55}$	4,409
Steam Ejector			600
Centrifuge		$97(F)^{.6}$	36,931

	30% Conc.	40% Conc.	50% Conc.
Base Cost	$246,946	$252,979	$255,764
Installed Cost	432,000	443,000	448,000
Depreciation	43,200/yr	44,300/yr	44,800/yr
Labor	16,000	16,000	16,000
H_2O	2,420	2,420	2,420
Electricity	20,180	20,180	20,180
Low Pressure Steam	17,960	18,900	19,360
Rotary Dryer Fuel Oil	22,000	14,160	9,440
Maintenance	17,280	17,720	17,920
H_2SO_4	9,220	9,220	9,220
Yearly Operating Cost	$148,260	$142,900	$139,340
Production Cost of Dried Solubles	2.54¢/lb	2.45¢/lb	2.39¢/lb

*F = feed rate to rendering plant in pounds of raw fish per hour.

TABLE II (Continued)

(e) 20 tons/hr, raw fish feed rate*

Equipment		Cost Equation	Cost
Tanks		$67(F)^{.53}$	$ 18,415
Pumps		$280(F)^{.21}$	2,592
		$37(F)^{.38}$	2,075
Evaporators:	30% outlet	$812(F)^{.55}$	275,860
	40% outlet	$838(F)^{.55}$	284,693
	50% outlet	$850(F)^{.55}$	288,770
Barometric Condenser		$19(F)^{.55}$	6,455
Steam Ejector			600
Centrifuge		$97(F)^{.6}$	55,977

	30% Outlet	40% Outlet	50% Outlet
Base Cost	$361,974	$370,807	$374,884
Installed Cost	633,000	649,000	656,000
Depreciation	63,300/yr	64,900/yr	65,600/yr
Labor	16,000	16,000	16,000
H_2O	4,850	4,850	4,850
Electricity	40,370	40,370	40,370
Low Pressure Steam	35,920	37,800	38,720
Rotary Dryer Fuel Oil	44,000	28,320	18,880
Maintenance	25,338	25,956	26,242
H_2SO_4	18,440	18,440	18,440
Yearly Operating Cost	$248,118	$236,636	$229,102
Production Cost of Dried Solubles	2.12¢/lb	2.03¢/lb	1.96¢/lb

*F = feed rate to rendering plant in pounds of raw fish per hour.

TABLE II (Concluded)

(f) 50 tons/hr, raw fish feed rate*

Equipment		Cost Equation	Cost
Tanks		$67(F)^{.53}$	$ 29,928
Pumps		$280(F)^{.21}$	3,142
		$37(F)^{.38}$	2,939
Evaporators:	30% conc.	$812(F)^{.55}$	456,621
	40% conc.	$838(F)^{.55}$	471,242
	50% conc.	$850(F)^{.55}$	477,990
Barometric Condenser		$19(F)^{.55}$	10,684
Steam Ejector			600
Centrifuge		$97(F)^{.6}$	97,000

	30% Conc.	40% Conc.	50% Conc.
Base Cost	$ 600,914	$ 615,535	$ 622,283
Installed Cost	1,052,000	1,077,000	1,089,000
Depreciation	105,200/yr	107,700/yr	108,900/yr
Labor	16,000	16,000	16,000
H_2O	12,120	12,120	12,120
Electricity	100,940	100,940	100,940
Low Pressure Steam	89,800	94,500	96,800
Rotary Dryer Fuel Oil	110,000	70,800	47,200
Maintenance	24,037	24,261	24,891
H_2SO_4	46,100	46,100	46,100
Yearly Operating Cost	$ 504,197	$ 472,421	$ 452,951
Production Cost of Dried Solubles	1.73¢/lb	1.62¢/lb	1.55¢/lb

*F = feed rate to rendering plant in pounds of raw fish per hour.

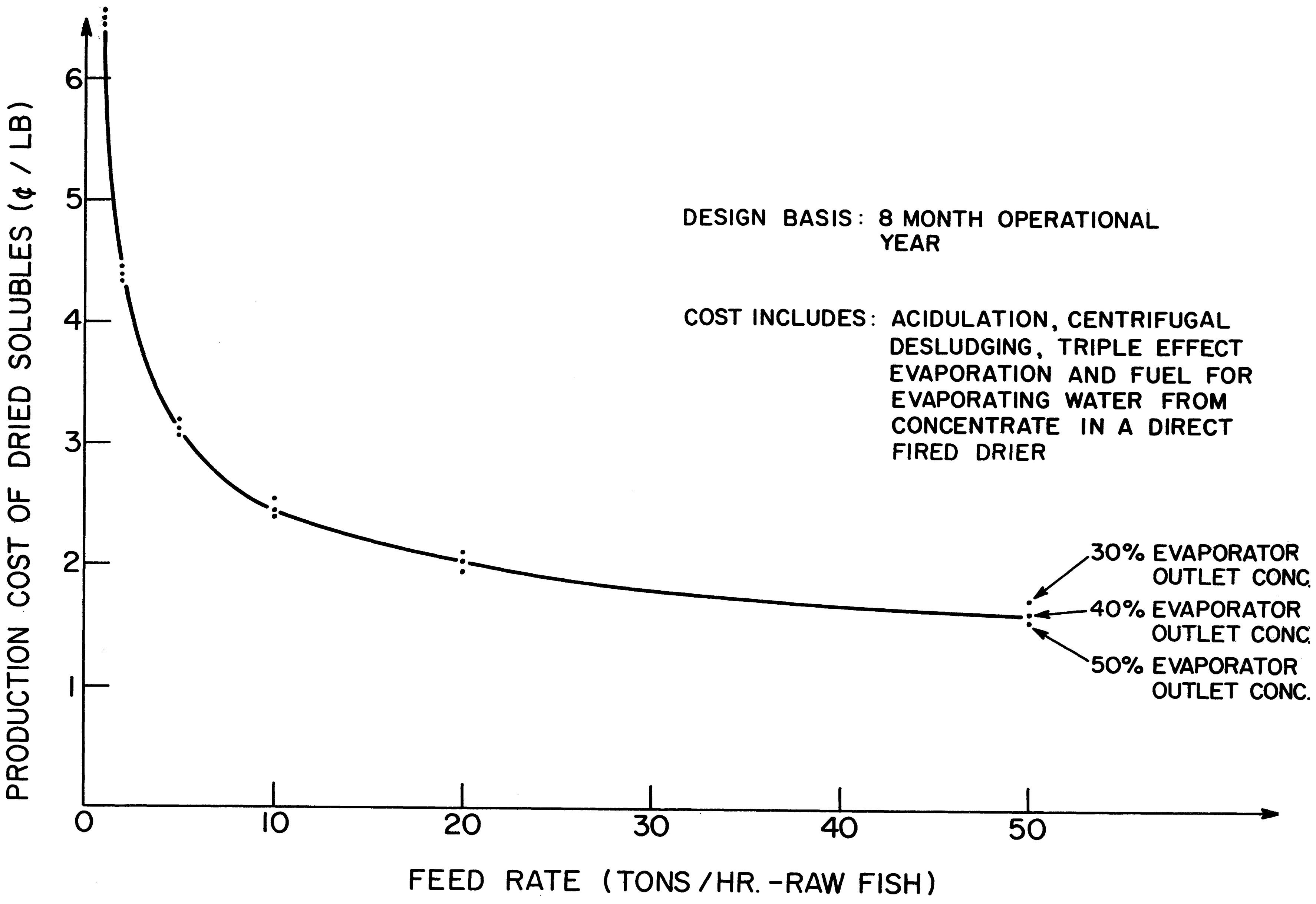


Fig. A-2. Production cost of dried solubles from stickwater by triple-effect evaporation.

One should note that the large part of the equipment cost is tied up in the evaporators and equipment, such as the centrifuge, which is needed to keep the evaporators operating. While this is not surprising, it does suggest that the processing cost might be reduced substantially by eliminating the centrifuge, substituting the evaporators with a more efficient system or a system which would not be subject to scale formation, etc., or drastically reducing the evaporator costs in some manner.

By observing Fig. A-2 one may see two trends. The first is that there is no significant reduction in production costs beyond a plant size of about 10 tons per hour. The other trend shows that it is more economical to evaporate the solubles to a high concentration in the evaporators before finish drying in the rotary driers than to stop the evaporation process at a lower solubles concentration.

Discussion

There are two potential pollution problems if this design is employed. First, the drain water from the second and third effects of the evaporator system and the drain water from the barometric condenser will probably contain small amounts of fish solids which may be entrained in the evaporate. This problem should be reduced by specifying demisters for the evaporators. However, the combined ($\sim$500 gpm) drain stream may have to be treated in a local waste treatment plant. If this potential problem materializes, the drain stream volume may be cut to about 10% by recycling barometric condenser feed water to a cooling tower and reusing it.

The other potential pollution problem involves odors from various parts of the operation. The tanks should all be covered to avoid as much of their contribution to the problem as possible. If serious odor problems are present, they may be eliminated by providing exhaust fans which constantly remove contaminated air and cycle it to the boiler furnace or to a scrubber system. The exit gases from the steam jet ejector will probably have to be cleaned or fed to the burners in this manner.

One potential disadvantage of this process is its fairly complicated and lengthy start-up and shut-down procedures. Multiple-effect evaporator systems must be run continuously in order to expect reasonable efficiencies. Unfortunately, fish are not often caught in a uniform manner. While they might be stockpiled to even out the plant operation, this would further complicate the odor problems.

Other problems may arise from the uncertainty of the centrifugation step. While the literature does indicate the need for centrifugation (11), little information is available to predict the size and speed of a commercial unit.

In addition, little property information of "stickwater" or solubles can be found. Information such as heat transfer coefficients and viscosities is needed to properly size the evaporators. Perhaps lab work would be needed to provide this information.

Conclusions and Recommendations

The triple-effect evaporation of "stickwater" from alewife rendering plants with subsequent addition to the meal can be a profitable operation. Within the limitations of the design basis, the minimum sized plant for profitable operation is one to two tons per hour.

While some existing plants include additional centrifuges and heat exchanger for more complete oil removal (12,13), this further complication seems unwarrented in the alewife industry since most of the oil is already removed and sold on the market. In fact, any method which would allow simplification of the suggested process should be investigated. Submerged combustion and spray evaporation are two other methods of concentrating the stickwater which could simplify operation by avoiding the potential problems of scale formation. Investigation of these two methods is recommended.

If there seems to be further interest in triple-effect evaporation, such subjects as scale formation, heat transfer coefficients, scorching of product, equipment resistance to corrosion, odor control, viscosity of concentrate at various concentrations and temperatures, disposal of condensed evaporate, and possible plant operating schedules must be investigated.

References

1. Paessler, A. H., and Davis, R. V., "Waste Waters from Menhaden Fish Oil and Meal Processing," *Proceedings of the 11th Purdue Industrial Waste Conference*, 1956, pp. 377-388.

2. Ziemba, John, "Stickwater Processing," *Chemical Engineering*, August, 1950, p. 133.

3. Paessler, *op. cit.*, pp. 377-388.

4. _____, "There's Good Hard Cash in Stickwater," *Food Industries*, *22*, 242-245, February 1950.

5. *Ibid*, pp. 242-245.

6. Stansby, H. E., *Industrial Fishery Technology*, Reinhold Publication Corp., New York, 1963, p. 232.

7. *Ibid.*, p. 232

8. _____, *op. cit.*, pp. 242-245.

9. Perry, J. H., *Perry's Chemical Engineers Handbook*, McGraw-Hill Book Company, Inc., New York, Fourth Ed., 1963, Sec. 20, p. 21.

10. Dryden, C. E., and Winfield, M. D., *Chemical Engineering Costs*, Ohio State University, Columbus, Ohio, 1963.

11. Paessler, *op. cit.*, pp. 377-388.

12. *Ibid*, pp. 277-388.

13. Ziemba, *op. cit.*, p. 133.

14. *Oil Paint and Drug Reporter*, March 4, 1968.

APPENDIX II

ECONOMIC EVALUATION OF STICKWATER CONCENTRATION BY SUBMERGED EVAPORATION

R. C. Scherr

Summary

This report is a preliminary study to determine whether or not submerged evaporation will be an economic method of concentrating "stickwater." Calculations were made to determine size and cost of equipment for a plant using such a process. From these figures, the manufacturing cost was determined based on a ten-year payout time on the equipment. The results were that the process was not only an economic method of handling this waste but a profitable one based on a sale price of meal of 6.35 cents per pound. It was therefore concluded that this process very definitely warrants considerations for handling this waste; and recommended that further work be done to determine the salability of the meal produced and the problems of air pollution concerned with this process.

Introduction

The processing of fish to fish meal produces a waste product called stickwater. Stickwater is essentially a "fish soup"; it is approximately 7-10% solids of which about 65% is protein. Presently the several fish meal plants in the Great Lakes area discharge this waste directly to the stream. The results are disasterous since the BOD of this substance is about 100,000 ppm and upon decaying produces obnoxious odors. A normal size plant produces a waste equivalent to a popultion of 15,000-20,000 people. Therefore, to treat this waste would be very costly.

Fish processing plants on the East Coast have installed triple-effect evaporation units to concentrate the waste. This concentrated "stickwater" or "fish solubles" is either sold as an animal food additive or added to the meal and dried to give additional meal.

At the present time concentration and subsequent sale or reuse of the stickwater seems to be the most economic and feasible solution to the pollution problem in the Great Lakes area. However, the initial cost and complexity of operation are not desirable for the size of plant located in this area. Therefore, this preliminary study of submerged evaporation for stickwater evaporation has been made. This is not a final design but a preliminary study made to determine if this process is cheaper and more profitable than triple-effect evaporation; and if it is, what further studies must be made in order to determine a final design for such a system.

The submerged evaporation system consists of a tank equipped with an oil burner. The hot gases from the burner pass through the liquid in the tank and evaporate the liquid by direct heat transfer. These gases may then be scrubbed to remove doors and entrained liquid. This system along with storage tanks and pumps is shown in Fig. B-1. The design closely follows that of Carpenter (1).

It should be noted here that this process is submerged evaporation. This differs from submerged combustion in that the combustion is done above the liquid and only the hot combustion gases are passed through the liquid. This is more desirable than submerged combustion where the fuel is burned below the liquid surface because scorching due to direct flame contact is avoided. However, scorching from the hot gases in submerged evaporation may still occur if the product is concentrated beyond 55% (1).

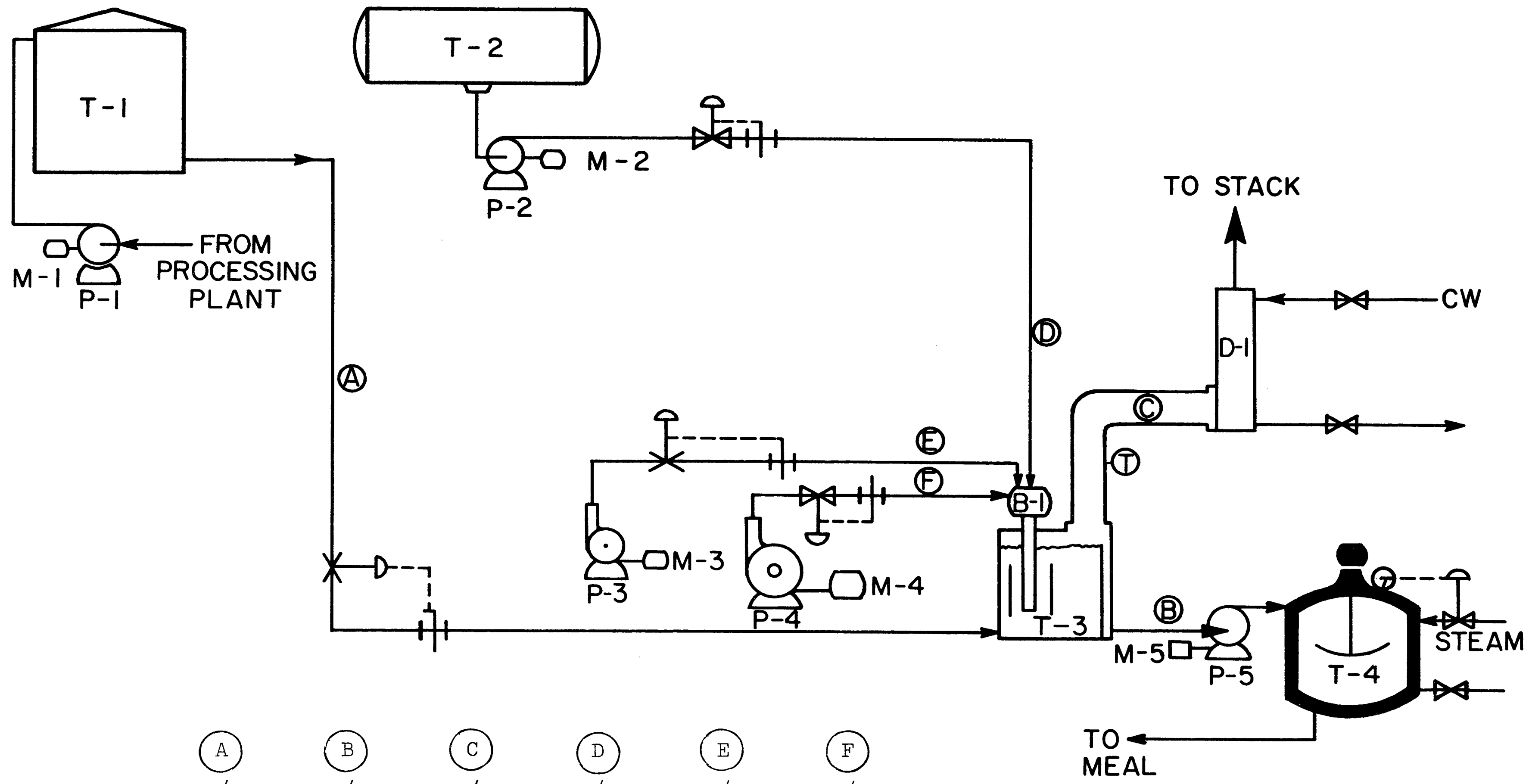
Design Bases

The work done by G. A. Carpenter on stickwater concentration (1) was used as a basis for the cost estimation. Mr. Carpenter presents complete heat and material balances for the operation of a two-ton per hour concentration plant. The mass balance from Carpenter's article is presented in Fig. B-1. These data were used to determine the heat balance for various sized plants. Since the majority of the heat was heat of evaporation the same ratios of heat required per ton of stickwater evaporated as presented by Carpenter were used in this cost analysis. As shown in Table IV, operating costs were based on continuous operation, 24 hours per day during an 8-month year.

Process

NORMAL OPERATION

During normal operation the "stickwater" is fed to the evaporator from the feed and storage tank (T-1) to the evaporator tank (T-3) by gravity. This stream is labeled stream A in Fig. B-1; and flow is regulated by a control valve in conjunction with an orifice. Evaporation takes place by passing the hot gases from the burner through the liquid in tank T-3. Since heat is



	(A) lb/hr	(B) lb/hr	(C) lb/hr	(D) lb/hr	(E) lb/hr	(F) lb/hr
Water	3838	450	3395	-	-	-
Solids	302	295	-	-	-	-
Oil	-	-	-	216	-	-
Air	-	-	5817	-	270	5330
Totals	4140	745	9212	216	270	5330
Temp., °F	182	182	187	134	-	-

Fig. B-1. Flow chart and mass balance. 2-ton/hr submerged combustion stickwater evaporation plant (after Carpenter (1)).

transferred directly from the gas to the liquid and no metal heat transfer surface is required there is no problem with scaling. The liquid leaves the tank over an overflow at a concentration of 40-50% solids and a temperature of 186°F; and is pumped to a storage tank (T-4) which is heated and stirred to prevent formation of a gel.

The burner is a standard oil burner supplied with air by two high pressure blowers (P-3 and P-4). Air and oil flow rates are all metered by orifice plates. It is necessary that the exit gas pipe be submerged at least three feet into the liquid being evaporated to allow for sufficient heat transfer. The hot gases and entrained liquid are then passed to a stack and either scrubbed or releated to the atmosphere. The blowers feeding the burner are sufficient to move the gases through a low pressure-drop scrubber. The scrubber has been shown in the design because, by most recent codes, it would be required. Since water requirements vary considerably with the type of scrubber used, exact calculations were not made, nor were they necessary to arrive at an approximate price for the required unit, since these units are all sized by gas volume (stream C).

To control the product concentration (stream B) it is only necessary to increase or decrease the inlet flow rate. The operation of this unit is therefore very simple and could be handled by one man no matter how large the capacity of the plant is.

START-UP

Start-up of this type of plant is quite simple; however, it will require four to five hours to reach equilibrium (1).

Operation is begun by filling the evaparator tank (T-3) with feed from stream A. The secondary air, stream E, is opened and the burner is ignited. The primary air is then adjusted to the proper flow. Oil and air ratio should be as shown in Fig. B-1. Feed is added to keep a constant level as evaporation takes place but no overflow is allowed. When the proper product concentration is achieved the feed is increased to the designed flow rate and the product will flow over the overflow baffle to stream B.

Equipment Design

The evaporator was patterned after the one used by Carpenter (1). The pumps and horsepower requirements were calculated by methods outlined in Chapter 6 of Perry's Chemical Engineers Handbook (2). Sufficient storage for four hours of feed and product were supplied, and storage for one month's supply of oil is provided. A complete equipment list along with cost sizing equations is provided in Table I.

TABLE I

EQUIPMENT SCHEDULE

Code	Name	Cost Equation
B-1	Burner	*$C = .243F$
D-1	Fume Collector	$C = 1.67\ (.464F)^{.89}$
P-1	Stickwater Feed Pump	$C = 77.84\ (.0018F)^{.53}$
P-2	Oil Feed Pump	$C = 77.84\ (9.4x10^{-5}\ F)^{.53}$
P-3	Primary Air Pump	$C = 456\ (.0136\ F)^{.59}$
P-4	Secondary Air Pump	$C = 98.96\ (.293\ F)^{.67}$
P-5	Solubles Pump	$C = 77.84\ (2.57x10^{-4}\ F)^{.53}$
T-1	Stickwater Feed Tank	$C = 792.9\ (2.17x10^{-3}\ F)^{.53}$
T-2	Oil Storage	$C = 689.4\ (.04052\ F)^{.53}$
T-3	Evaporator Tank	$C = 367\ (.00375\ F)^{.55}$
T-4	Solubles Storage	$C = 756\ (.015\ F)^{.5}$
M-1	P-1 Drive $(10^{-5}\ f)$hp	
M-2	P-2 Drive $(2.7x10^{-6}\ F)$hp	
M-3	P-3 Drive $(.00184\ F)$hp	$C = 70.8\ (F)^{.61}$
M-4	P-4 Drive $(7.4x10^{-9}\ F)$hp	
M-5	P-5 Drive $(1.8x10^{-6}\ F)$hp	

Reference: Chemical Engineering Costs, Dryden (3).

Combined Equations:

P-1, P-2, P-5

$$C = 4.28\ (F)^{.53}$$

T-1, T-2

$$C = 156.8\ (F)^{.53}$$

(M-1) (M-5)

$$hp = 2.5995\ x10^{-3}\ F$$

P-1, P-2, P-5, T-1, T-2

$$C = 161.06\ (F)^{.53}$$

*Note: F = lb/hr.

Economic Evaluation

The cost of the equipment was determined by methods outlined in Dryden's Chemical Engineering Costs (3). The cost equation for the burner was determined from W. L. Nelson's Cost-Imating (4). These equations are listed for each piece of equipment in Table I. After the installed equipment cost was determined the fixed capital investment was determined by using percentages of equipment costs as shown in Table II. It was found that the fixed capital investment was approximately 1.75 times the installed equipment cost. This is lower than would be expected from Lang factors but this is because of the simplicity of the process.

TABLE II

FIXED CAPITAL INVESTMENT

Equipment cost (EC) is calculated from Table I. Other costs are a function of EC.

Expense	% of EC
Instrumentation	10%
Insulation	5%
Piping	5%
Foundations	5%
Structures	5%
Electrical	5%
Painting and Clean up	4%

Installed Cost = IC = 39% of BC + EC

	% of IC
Engineering	13%
Contingencies	12%
	25% of IC or
	35% of EC

therefore I_F = 1.75 EC.

The manufacturing cost is outlined in Table III. The most significant operational cost for most sized plants is the fuel cost. This is what is expected since this system entails essentially only the evaporator and a few pumps.

TABLE III

OPERATIONAL COST

Based on an 8-month operational year and a 24 hr day
(143 lb meal/ton of feed)

Expense	Basis	Cost Equation
Depreciation	.10 I_F - 10-year payout	--
Labor	1 man at $10,000 per year	--
Utilities:		
Water	$.02/M gal - for scrubber	C = .032 (F)
Oil	No. 6 $.08/gal	C = 2.5 (F)
Electricity	$.02 lkw-hr	C = .22 (F)
Steam (Drying)	1/2 lb/lb product at .30/M lb	C = .06 (F)
Maintenance	.04 I_F	--

A Summary of Fixed Capital Cost and Manufacturing Cost is presented in Table IV. From Table IV, the fixed capital required for a ten-ton per hour plant is $226,720, about half of that expected for a similar plant using triple-effect evaporation. The manufacturing cost for a plant this size is 2.12 cents per pound of added meal produced. The current sale price of meal according to the Oil Paint and Drug Reporter (5), is 6.35 cents per pound. Therefore, it seems that this process could become profitable for this size of plant. In fact, at all plants processing between one and fifty tons of stickwater, a profit is possible.

Conclusions

It would seem that this process would be very suitable for use in the Great Lakes area. However, it is recommended that pilot operations be set up to determine the quality and salability of the meal produced by such a process. This is necessary because the sale price for meal varies greatly with quality. If any scorching occurs at all, it may reduce sale price considerably. It is also necessary to determine how well odor may be controlled by scrubbers on the effluent vapor. These stack effluents must be able to meet new air pollution acts as passed by Michigan last year.

The low cost and possible profits from this process to treat a waste, which otherwise would certainly be an added expense, very definitely warrant further consideration and research.

TABLE IV

COST COMPARISON OF SUBMERGED EVAPORATION SYSTEMS FOR CONCENTRATING STICKWATER AT VARIOUS SIZED FISH RENDERING PLANTS

	Plant Size Based on Stickwater Processed					
	1 ton/hr	2 ton/hr	5 ton/hr	10 ton/hr	20 ton/hr	50 ton/hr
Plant Cost:						
Equipment						
Burner	$ 487.00	$ 972.00	$ 2,430.00	$ 4,870.00	$ 9,720.00	$ 24,300.00
Fume Collector	730.86	1,354.41	3,061.38	5,673.28	10,311.68	23,763.89
Liquid Pumps	240.43	347.16	564.21	814.68	1,176.35	1,911.81
Primary Blower	3,201.55	4,819.13	8,274.71	12,455.48	18,748.57	31,192.36
Secondary Blower	6,363.36	10,124.56	18,706.65	29,094.50	47,356.14	87,497.59
Feed Tanks	8,808.30	12,718.56	20,670.27	29,846.40	43.096.09	70.039.99
Evaporator Tank	1,111.60	1,627.48	2,693.91	3,944.12	5,774.52	9,558.36
Solubles Tank	4,140.78	5,855.95	9,259.07	13,094.30	18,518.14	29,279.75
Pump Drives	7,305.70	11,150.38	19,499.94	29,761.96	45,424.47	79,438.91
Total Equipment Cost	$32,389.58	$48,969.93	$85,160.14	$129,554.72	$200,125.96	$356,982.66
Fixed Capital Investment: I_F From Table II I_F = 1.75 (equip)	$56,600.00	$85,700.00	$149,030.00	$226,720.00	$350,220.00	$624,720.00
Operating Cost (8 months):						
Depreciation	$ 5,660.00	$ 8,570.00	$14,903.00	$ 22,672.00	$ 35,022.00	$ 62,472.00
Labor	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00
Utilities						
Water	6,400.00	128.00	320.00	64.00	1,280.00	3,200.00
Oil	5,000.00	10,000.00	25,000.00	50,000.00	100,000.00	250,000.00
Electricity	440.00	880.00	2,200.00	4,400.00	8,800.00	22,000.00
Steam (Drying)	120.00	240.00	600.00	1,200.00	2,400.00	6,000.00
Maintenance	3,172.80	4,679.47	7,858.40	11,631.60	17,406.32	29,746.96
Total Operating Cost	$24,456.80	$34,497.47	$60,881.40	$100,543.60	$174,908.32	$383,418.96
Pounds of dried solubles per year at 5% solids feed	576,000	1,152,000	2,880,000	5,760,000	11,520,000	28,800,000
Cost per pound of dried solubles	4.25¢	3.01¢	2.12¢	1.75¢	1.52¢	1.37¢

Sale Price: 6.35¢/lb

References

1. Carpenter, G. A., "Submerged Evaporation and Its Application to Fish-Stickwater Recovery," Chem. & Process Eng., 39, 425-428, Dec. 1958.

2. Perry, J. H., Perry's Chemical Engineers Handbook, Fourth Ed., McGraw-Hill Book Co., New York, 1963.

3. Dryden's Chemical Engineering Costs, Ohio State University, 1966.

4. Nelson, W. L., "Cost-Imating," from Oil and Gas Journal, 1949.

5. Oil Paint and Drug Reporter, March 4, 1968.

Additional References

Bartholomew, F. J., "Chemico's New Pickle Liquor Process," Chem. Eng., 57, Aug. 1950, p. 133.

Cronan, C. S., "Submerged Combustion Flares Anew," Chem. Eng., 63, Feb. 1956, pp. 163-167.

Austin, J., British Chemical Engineering, 64, Feb. 1957, p. 490.

Rey, G. E., "Entrainment from a Submerged Combustion Evaporator," AIChE J., 7, 299-302 (1961).

Weisman, W. I., "Submerged Combustion Equipment," Ind. Eng. Chem., 53, 708-712 (1961).

Williams, A., "Submerged Combustion for Distilled Water Plants, Mech. Eng., 87(7), 34-37 (1965).