Engineering and Economic Aspects of Continuous Soapstock Acidulation

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Abstract

Recovery of 98–100% of the total fatty acid content of soapstock may be achieved by continuous acidulation of soapstock with minimum acid consumption. The relatively high reaction pH allows the use of ordinary stainless steel equipment. By use of a two-stage separation process, quality acid-oil may be produced from even the most difficult foots, with a by-product stream high in phosphatides. Acid water from the system is suitable for waste disposal with little or no additional treatment.

Analysis of the process economics as compared to conventional batch acidulation shows that a 2–4 year system payout may be realized through acid savings, improved oil yield, and reduced labor costs.

Introduction

DUE TO THE low profit contribution available from processing of vegetable oil refinery soapstock, very little development work has been done in the past to improve the antiquated, poorly controlled, and relatively expensive batch acidulation method for acid oil recovery. Conversion of the batch tank method to continuous processing was further impeded by the extremely corrosive conditions prevalent in the batch process. During the past few years, increased interest in plant waste streams by the government has forced a reassessment of soapstock treatment. A result of this interest has been the development of a continuous, automatically controlled soapstock acidulation process which not only offers a solution to the waste disposal problem, but through savings in reagents, labor, and increased acid oil yield and quality, shows a reasonable system payout.

Process Description

A schematic flow diagram of a complete system for processing nondegummed oils is shown in Figure 1. Soapstock is fed to a surge tank, where it is blended with water, if necessary, to provide an acidulation feed mixture of pumpable viscosity, and a total fatty acid content below 25%. Liquid level control may be achieved by means of a weight-cell at the tank, controlling a pneumatic operator on the soapstock feed pump. A hot water line is provided at the feed pump suction, for system heating, and cleaning. Soapstock is pumped continuously through a steam jet heater to the high shear mixer. The inlet temp to the mixer is automatically controlled at 190–200F, to provide the required speed of reaction. 66° Be' sulfuric acid is metered into the soapstock stream at the point of entry into the mixer. The acid rate is automatically controlled to give a pH of 3.5–4.0 after completion of the reaction. Temp rise due to heat of reaction is normally 5–15F. A plate heat exchanger is used to reduce the reaction mixture temp to that desired for acid oil separation, again with automatic temp control.

Separation of the acid oil from acid water and solids is accomplished in a self-opening centrifuge, which in addition to making the normal liquid/liquid separation, has provisions for automatic "shooting" of accumulated solids from the centrifuge bowl. Shooting is controlled by a timer, which ordinarily is set for a 15–20 min interval. Solids removal takes 10–15 sec, and may be accomplished, in many cases, without interruption of feed to the separator.

For soapstocks without phosphatide fractions, the acid oil discharged from the primary separator is suitable for marketing without further processing, with up to 96% TFA content. Since the recovery of acid oil is above 99% on such soapstocks, the acid water phase is virtually fat-free, and suitable for disposal after neutralization. In the case of soapstocks with substantial gums content, however, four phases
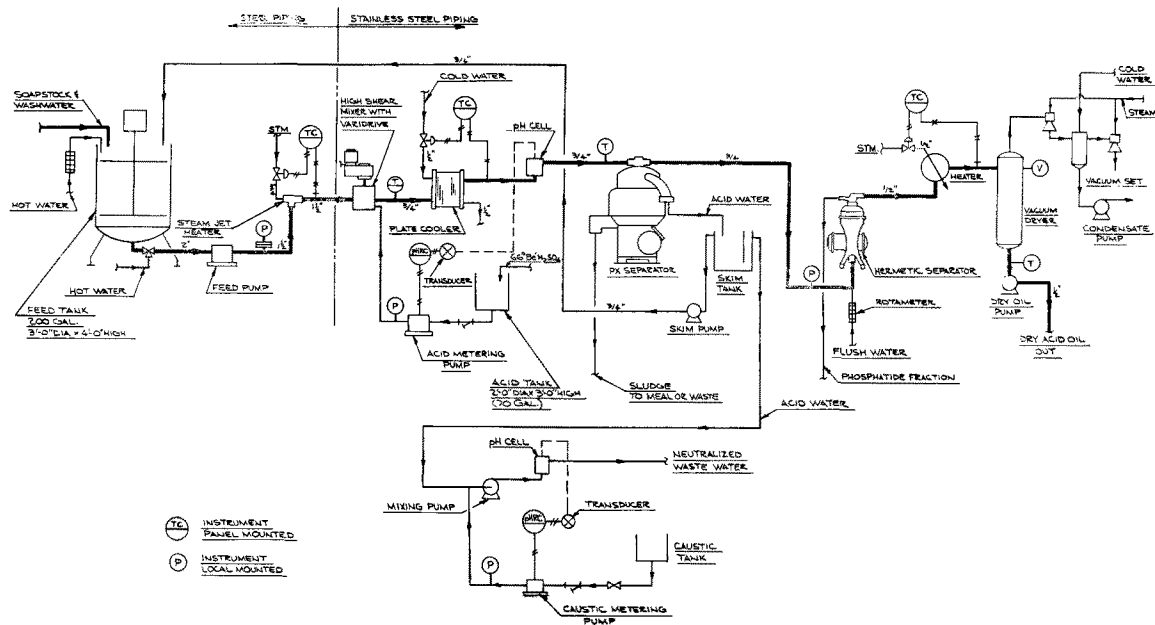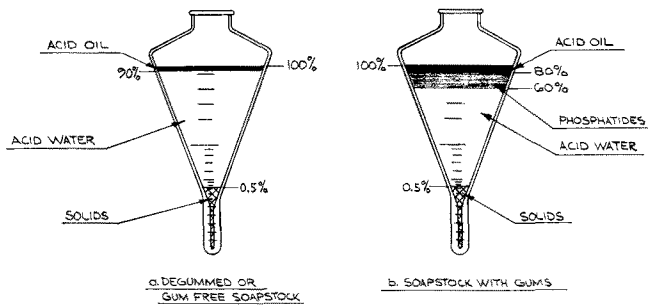

FIG. 1.

FIG. 2. Typical centrifugal separation, acidulated soapstock.

exist in the primary separator bowl, as is illustrated in Figure 2.

At a reaction pH of 3.5–4.0, a large portion of the phosphatide phase is unreacted. Upon separation, this phase appears between the acid oil and water layers. Since this fraction is principally oil-wet, it is normally discharged from the primary separator as part of the acid oil, allowing a relatively clear acid water phase to be discharged. Since the acid water in this case does contain phosphatide degradation products, it therefore must be clarified after neutralization, prior to sewering. This should normally be accomplished in the usual plant waste treatment system. In order to eliminate occasional floating solids in the acid water phase, a skim tank may be provided on the acid water stream. This allows recycling of all floating solids, in addition to up to 25–30% of the acid water phase. Acid water recycling decreases

the requirement for dilution water, and may reduce the acid requirement in acidulation by as much as 15%.

The acid oil phase normally contains 10–25% phosphatides, by vol. Although the TFA level is high enough for use as feed supplement (above 87%) (1), the pasty, viscous nature of the mixture, and the low pH of the entrained moisture makes it rather poor quality material for marketing. The phosphatide level makes the oil completely unacceptable as distillers' feedstock.

A high quality acid oil may be recovered from the acid oil-phosphatide mixture by further centrifugation in a Hermetic separator. The addition of a small amt of water to the centrifuge feed not only aids in discharging phosphatides from the centrifuge bowl, but effectively washes mineral acid from the acid oil, as indicated by acid oil ash pH levels above 6. Separated acid oil is normally above 90% TFA content and contains 85% of the TFA content of the original soapstock. If a price premium can be obtained on acid-oil above 95% TFA content, vacuum drying of the phosphatide-free acid-oil may be employed to reduce the soluble moisture content to less than 1%.

The phosphatide phase, containing only 15% of the fatty acid, is suitable for addition to feed meal, if such an outlet is available to the processor. Further treatment of the phosphatide phase is not considered justified by the small potential oil recovery.

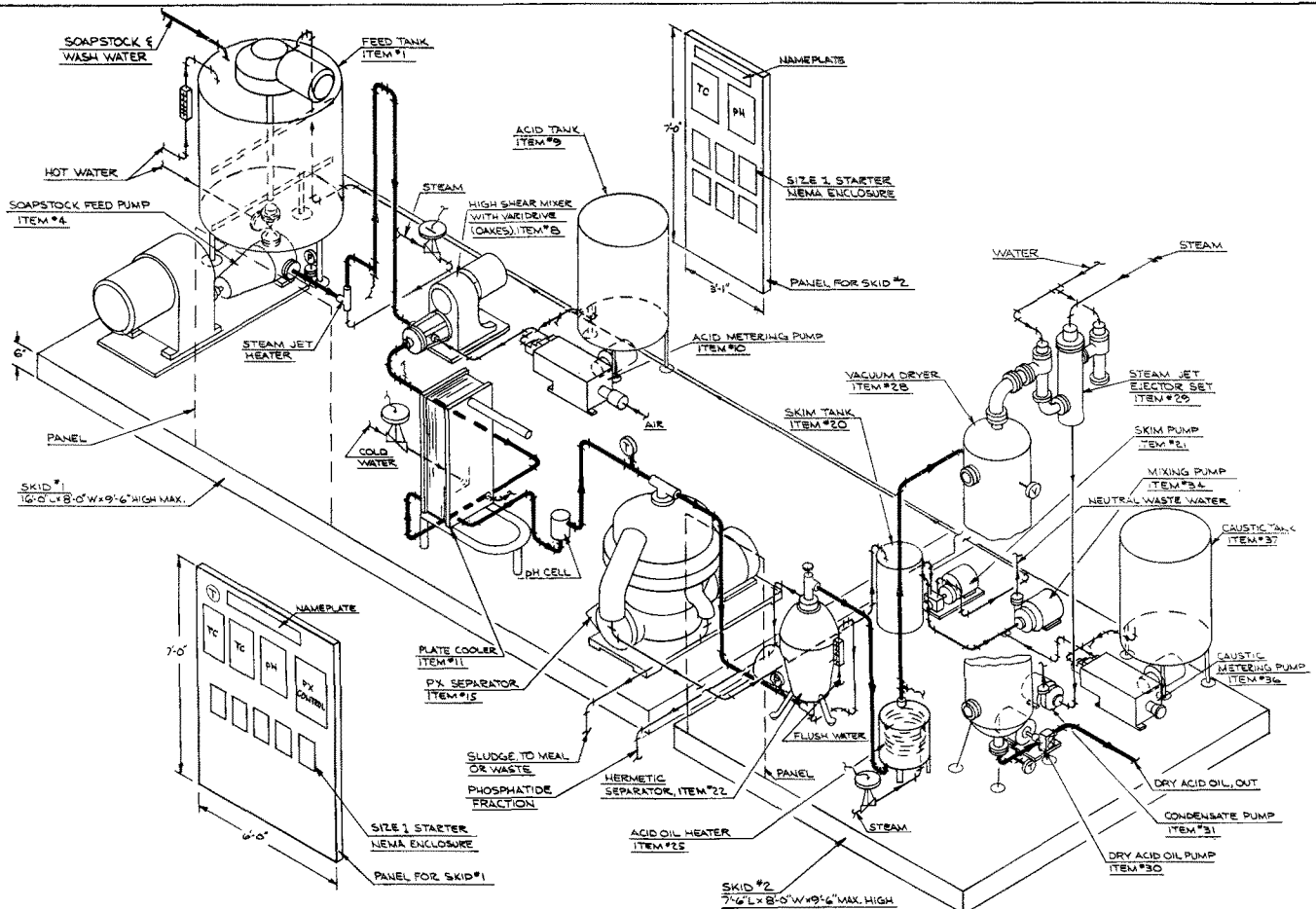A major advantage of the relatively high operating pH in this process is the use of ordinary 316 stainless

FIG. 3.

TABLE I

Continuous Soapstock Acidulation Maximum Utilities Consumption

Power
23½ Connected H.P.
17.6 kw hr/hr @ 1.5¢/kwh... $0.26

Steam
1500 pph @ 1.00/1000 lb.. 1.50

Water
40,000 lb/hr @ $0.20/1000 gal. 0.96

Air
15 SCFM.. Negligible
Total hourly cost:... $2.72
Cost per lb 95 TFA oil @
5,000 pph @ 20% TFA feed.... .... $0.0026

TABLE II

Economic Comparison, Batch vs Continuous Acidulation of Non-degummed Soybean Soapstock. Basis: 5000 pph Feed at 20% TFA, (Annual Production) Plant Cost, Two Stage System: $75,000 est. 20 hr Operation/Day, 300 Days/Year

	Batch acidulation	Continuous acidulation	Savings (loss)
Labor..................................	$ 7,500	a	$ 7,500
Acid	64,000	$ 29,500	34,500
Caustic soda	50,000	12,000	38,500
Utilities..............................	15,000	16,400 b	(1,400)
Maintenance	3,750	3,750 c	0
Acid oil yield	590,000	671,000	81,000
Phosphatides (as soapstock)...............	......	42,000	42,000
			$202,100

Total profit contribution ignoring depreciation:
a Operated by refinery operator.
b Absolute maximum, i.e., using total connected HP, and no reuse of waste water for dilution or cooling.
c Estimated maximum, 5% of equipment cost.

steel equipment after the point of acid addition. The only area subject to an extremely corrosive mixture is the acid inlet, at which point a ceramic or glass tee is utilized to withstand acid attack.

Commercial grade, 66° Be' sulfuric acid is used as a reagent, eliminating costly acid dilution systems. Acid usage is generally in the range of 0.2 to 0.3 lb per pound of fatty acid produced on a 100% TFA basis.

The compactness of the soapstock acidulation plant is illustrated in a proposed, skid-mounted system in Figure 3.

The basic, single stage system for processing of soapstocks low in phosphatides, is mounted on a skid measuring only 16 ft × 8 ft × 9 ft 6 in overall height. The auxiliary equipment required for production of high quality acid oil from raw materials containing gums may be mounted on a second skid, 7 ft 6 in × 8 ft × 9 ft 6 in high. Both skids may be transported by low-bed trailer, and are ready for operation after connection of water, steam, air and waste lines to the plant manifolds, and power to the main starter frame. Utility requirements for a 5,000 pph soapstock capacity are as shown in Table I.

Dollar costs of utilities are based on national averages of utility prices, and plant steam cost estimates as recommended by Zimmerman and Lavine (2). Costs are on an hourly basis, but may be converted to a unit cost by dividing by the TFA rate per hour, as shown for 20% TFA feed material.

Economic Justification

Economic justification for the purchase of a continuous acidulation system may be demonstrated in a comparison of batch acidulation costs with those for continuous acidulation.

A feed rate of 5000 pph of 40% TFA, nondegummed soybean soapstock has been chosen for comparison (Table II).

Labor savings are based on the fact that the continuous soapstock acidulation system may be operated as a part of the existing oil refinery, without the use of additional operating personnel. The use of automatic pH and temp controls reduce operator observation to an absolute minimum (1). Ordinary fluctuations in feed composition have no effect on process operation. For batch acidulation, it has been assumed that a minimum of one man-shift per day is consumed during periods of acid addition, and draining of waste and product after acidulation. In the case of nondegummed oil soapstocks, additional operator time is required due to the extreme care necessary to achieve high acid-oil yields in the presence of phosphatides.

Acid consumption in the high pH, continuous acidulation process are less than half of that in even a well-controlled batch process, where pH's as low as 1.0–1.5 are common. Assuming the use of caustic

soda for neutralization of this excess acid, even more substantial savings may be realized in the treatment of acid water waste. Caustic usage in batch systems is more than four times that in the continuous acidulation process. In addition, the uniform waste water rate from the continuous plant lends itself very nicely to automatic pH control in neutralization.

The yield of high quality acid oil from the two stage continuous process has shown to be 85% of the available TFA with the balance of the TFA being collected in the phosphatide fraction. Unless extreme care is used, a batch acidulation process applied to nondegummed foots cannot be expected to yield more than 75% of the available TFA as high quality oil, with the balance, unreacted phosphatides, and degradation products, going down the drain in the waste water stream. It must be pointed out, in addition, that the relatively mild treatment of foots in the continuous process results in oxy-fatty acid levels below 2% in the finished oil, as compared to 4% or higher from the batch process.

An additional dollar yield may be expected from the separated phosphatide fraction, which, at 40% TFA on a dry basis, may be used as feed supplement in the same manner as the original soapstock.

The magnitude of the overall cost reduction comes into focus when compared to the total value of the acid oil produced. On the material taken as an example, the savings amount to 35% of the market value of the product oil.

A final advantage of the continuous acidulation process lies in control of the refinery operation. By monitoring the acid oil FFA, and the appearance of the acid water waste stream, an operator may quickly and continuously determine his refining efficiency.

In summary, this simple, compact, automatically controlled process will continuously recover 98–100% of the total fatty acid from even the most difficult soapstocks. The use of a self-cleaning centrifuge for primary separation, plus automatic control brings operator attention to an absolute minimum.

By use of a relatively high reaction pH, substantial savings in reagents are achieved, in addition to allowing the use of ordinary stainless steel process equipment.

The overall savings in labor and reagents, coupled with a consistently high acid-oil yield offer a reasonable system payout over the conventional batch acidulation process.

REFERENCES

1. Poultry Science 5, 273–278 (1957).
2. Zimmerman, O. T., and I. Lavine, Industrial Research Service, (1950).