Production of Gossypol from Cottonseed Gums. Preliminary Cost Study

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THE FIVE MILLION TONS of cottonseed produced annually in the United States and 16 million tons produced in the world contain approximately 60 million pounds and 200 million pounds of gossypol, respectively.

"Gums" produced commercially in one oil mill by water-washing contain approximately 5% gossypol and are a potential source of 200,000 lbs. of gossypol annually. These gums are currently added back to the hexane-wet meal in order to increase the capacity of the desolventizer, reduce meal dustiness, increase ease of pelleting and pellet output, raise fat content and increase protein solubility and nutritive value of meal. Additional premiums are realized for the oil because of lower refining loss (3).

With the SURDD process of gossypol recovery from cottonseed gums (6), 81,000 lbs. of gossypol could be extracted annually at the above-mentioned mill. Phosphatides, which are also produced, could be returned to the meal in place of the gums or marketed as high grade, unbleached lecithin. If the phosphatides are not added back to the meal, acidulated or raw soapstock might be substituted for the gums.

Using this process, the Southern Utilization Research and Development Division produced large quantities of pure gossypol, which have been made available for nutritional investigations of the physiology of gossypol in the feeding of swine and poultry, for research on improving process methods for seed and oil, for use as a standard analytical reagent (4), and for numerous other uses.

At this time there are no uses for gossypol to justify commercial production, but research is currently under way to develop uses for the compound as a chemical intermediate. Because of the great reactivity of its phenolic, carbonyl, methyl, and isopropyl groups, gossypol has great potential as a starting material for the synthesis of a number of organic compounds of unique structure.

A chemical balance and complete flow diagram for the production and purification of gossypol-acetic acid and its conversion to gossypol is shown in Figures 1 and 2.

Plant Investment

This cost study is based on the construction and operation of a hypothetical continuous plant with a capacity for extracting gossypol from cottonseed gums at a rate of 81,000 lbs. annually.

Estimated total plant investment costs for the various types of plants for producing either crude gossypol-acetic acid, pure gossypol-acetic acid, or pure gossypol are shown in Table I.

A material balance was prepared, based on pilot-plant and laboratory-scale runs. By applying the flow rates and yields obtained from the material balance

TABLE I

Gossypol Extraction Process—Total-Plant Investment and Total Manufacturing Costs

	Pure gossypol		Crude gossypol-acetic acid	Purified gossypol-acetic acid
	Recommended	Minimum		
Annual production (1,000 lbs.)	81	81	113.5	100.2
Annual operation (days)	330/25	330/25	330	330/25
Daily operation (hours)	24	24	24	24
Total plant cost ($)	802,110	540,875	329,285	565,285
Manufacturing costs (¢/lb.):				
Direct costs				
Chemicals	80.2	36.4	48.4	59.7
Labor	93.0	56.2	61.7	75.1
Utilities	10.2	6.4	6.6	7.9
Other (Supervision, maintenance, and plant supplies)	70.9	31.4	25.9	43.7
	254.3	130.4	142.6	186.4
Indirect costs (Payroll overhead, general plant overhead, control laboratory and packaging costs)	61.9	35.7	39.4	48.0
Fixed costs (Insurance, taxes, and depreciation)	108.9	73.5	31.9	62.1
Contingencies	21.3	2.4	10.7	14.8
General expenses (Gen. adm. and off. overhead, financing and sales costs)	108.6	63.0	38.7	69.4
Total manufac. costs	555.0	305.0	263.3	380.7
($/lb.)	5.55	3.05	2.64	3.80

to the known gums output of a direct solvent-extraction plant, it became apparent that, with a continuous process, the rate of production of gossypol would be extremely low. Therefore it was decided to perform Phase No. 1, conversion to gossypol-acetic acid, concurrently with the operation of the mill, storing the crude material for purification at a later time. During periods of shut-down, which were assumed to total somewhat less than a month, Phases Nos. 2 and 3, purification of the gossypol-acetic acid and conversion to gossypol, respectively, would be accomplished. The flow rates were so adjusted that all of the crude acid produced and stored from Phase No. 1 could be converted to gossypol in the period of time allotted. In an effort to reduce costs, equipment from Phase No. 1 was used in Phase No. 2 if capacity permitted.

Investment costs for equipment were for the most part compiled from costs furnished by equipment manufacturers. Stainless steel equipment would be used in most cases on account of the corrosive nature of some of the chemicals.

The total physical-plant costs were derived by the addition of installed equipment cost, process piping, instrumentation, auxiliary facilities, and buildings, which were calculated by applying percentages to purchased equipment costs (1, 2, 5, 7). Engineering and construction costs and contingencies, each assumed to be 25% of the total physical-plant costs, were added to the total physical-plant costs, to obtain the total plant cost. One total-plant cost for the entire process

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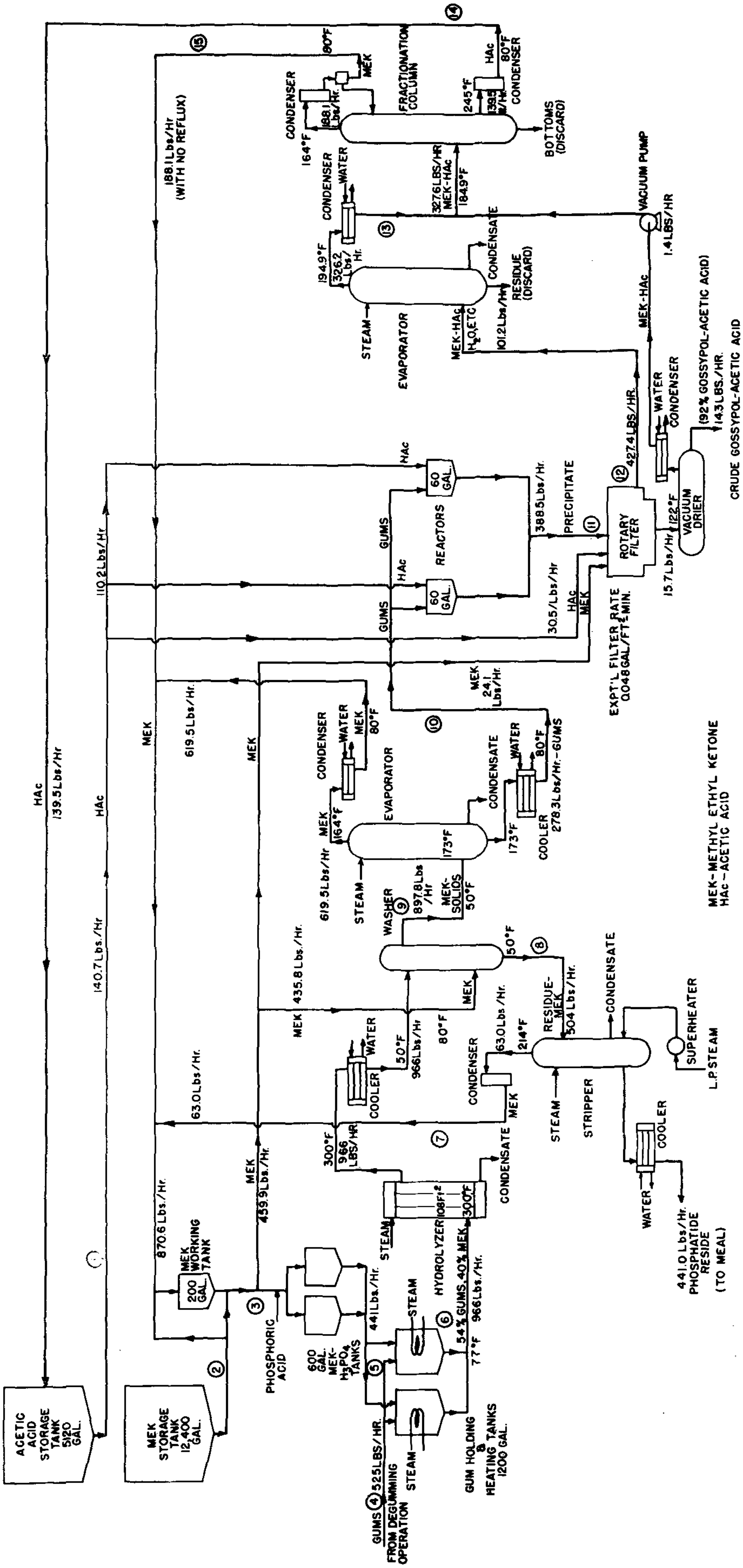

FIG. 1. Phase I. Flow sheet for recovery of gossypol-acetic acid from cottonseed gums.

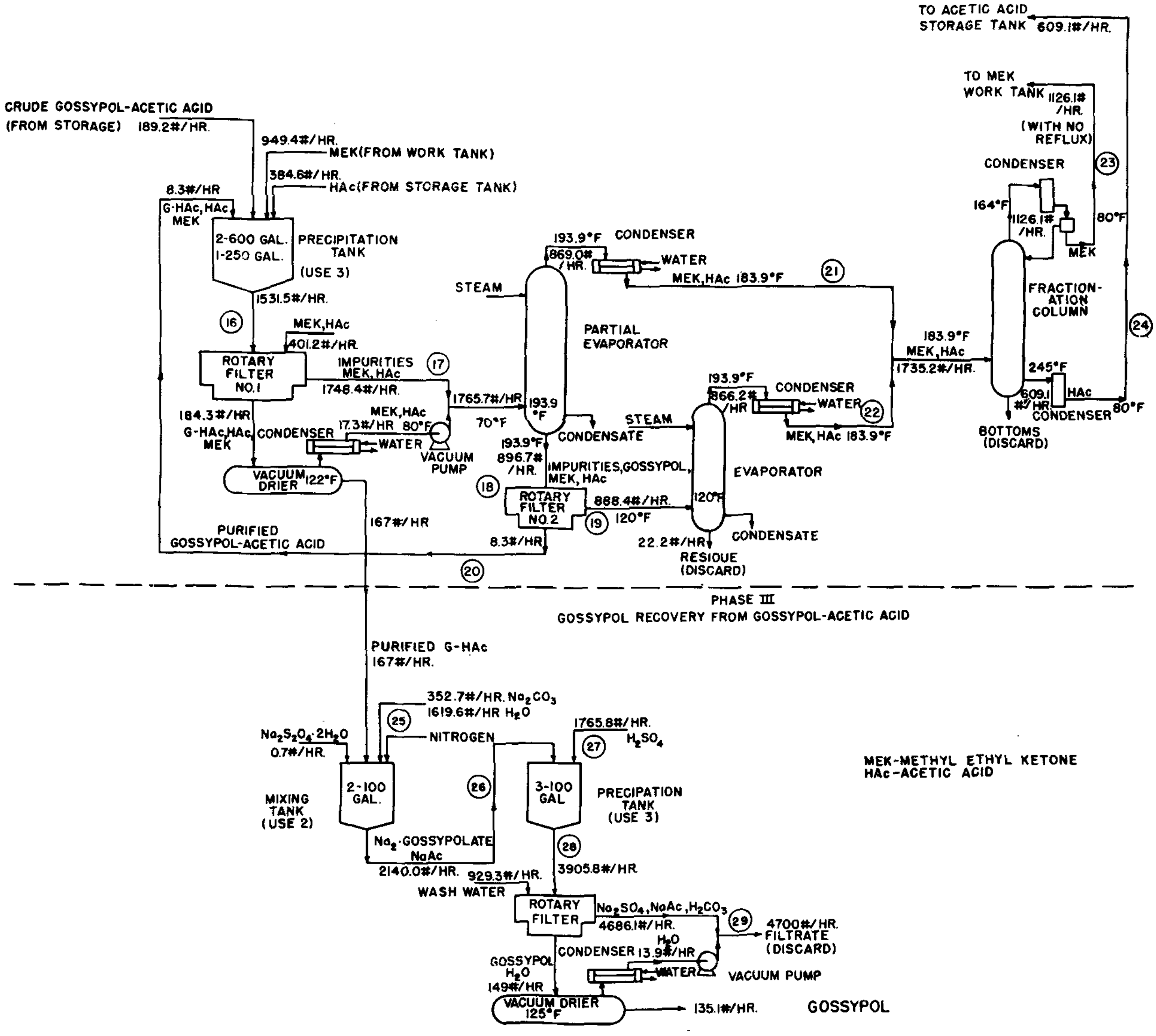

FIG. 2. Phase II. Purification of gossypol-acetic acid.

was estimated by using percentages considered to be most applicable to the process. A minimum total-plant cost was also estimated by using minimum factors not necessarily recommended. That part of the total manufacturing cost for producing crude and purified gossypol-acetic acid is also reported separately.

Processing, with the exception of all acetic acid and methyl ethyl ketone-recovery operations, would be carried out indoors. A building was allowed for processing and for product storage. This building, which could be erected adjoining or near the existing mill, is of single-story steel-frame construction with corrugated iron for the roof and walls.

Basing the calculations on a mill operating 330 days per year and assuming that the purification and conversion operations would be carried out during a 25-day period, the following investment costs were derived: $802,110 for the entire plant, using recommended percentage figures; $540,875 for the entire plant, using minimum percentage figures; $329,285 for the plant producing only crude gossypol-acetic acid; and $565,285 for the plant producing only purified gossypol-acetic acid.

The total-plant costs for producing the intermediates were not calculated with minimum percentages, but these costs would relate to those shown in Table I in the same proportion that the two plant costs for producing pure gossypol are related (approximately 2/3).

If, instead of returning the phosphatides to the meal, it is decided to market them as unbleached lecithin, additional equipment such as a dryer, vacuum pump, and condenser would be required. This would represent an additional total-plant cost of $92,285. The mill would then have to substitute a material, such as acidulated soapstock, for the gums. To allow for 14 days' storage of the soapstock, a stainless-steel tank would be required, costing $14,000 installed.

Manufacturing Cost

In this paper total manufacturing cost is the sum of direct, indirect, and fixed costs, contingencies, and general expenses.

The estimated total manufacturing costs for producing 81,000 lbs. of pure gossypol annually, using both recommended and minimum percentages are $5.55 and $3.05 per pound of product, respectively. For producing 113,500 lbs. of crude gossypol-acetic and 100,200 lbs. of purified gossypol-acetic acid annually, the estimated total manufacturing costs are

\$2.64 and \$3.80 per pound of product, respectively. Additional total manufacturing cost for producing 3,409,600 lbs. of crude phosphatides annually is 9.1¢ per pound of phosphatide. If this cost is subtracted from the market value of unbleached lecithin, which is currently 13¢ per pound, a profit of 3.9¢ per pound is realized. Converting this profit to the gossypol equivalent would result in a profit of \$1.64 per pound of gossypol. This profit, when credited to the manufacturing cost of gossypol, would reduce the total manufacturing cost from \$5.55 to \$3.91 per pound.

The direct manufacturing costs, in most cases, were found to account for the greater portion of the total manufacturing costs. Chemical requirements were determined from data obtained from laboratory and pilot-plant runs. In the calculation using recommended percentages, 95% recovery of the methyl ethyl ketone was used, and in the calculation using minimum percentages, 99% methyl ethyl ketone was used. In all cases 98% recovery of acetic acid was assumed, with no recovery allowed for the other chemicals. If the phosphatides are not to be returned to the meal, a value should be assessed the gums to be used in the process to allow for the purchase of acidulated soapstock, which would be used instead of the gums in the cottonseed meal. Therefore an additional chemical cost of \$166,320, or 4¢ per pound of gums, was allowed.

Direct labor costs were based on process labor requirements (1, 5) with the wage rates adjusted to current scales for skilled labor and foremen. Overtime and night differential rates were also applied when necessary. The labor used for Phase 1 was also used for Phases 2 and 3.

Utility costs include those for steam, electricity, process and cooling water. Unit steam cost of 50¢ per 1,000 pounds was used (5). Since steam-generating facilities are presently in use at the mill, on which this cost study is based, it was assumed that additional demands made on their boiler would not overtax its capacity.

Electric power costs were estimated by using a unit cost of 1¢ per kwh (5). City process water was used at a cost of 20¢ per 1,000 gal. (5). Cooling water was to be supplied by a tower, currently in use, at a cost of 3¢ per 1,000 gal. (5).

General expenses are those for general administration and office overhead, financing, and sales costs.

Summary

Based on operations of a hypothetical gossypol-extraction plant, it is estimated that crude gossypol-acetic acid can be produced at a cost of \$2.64 per pound at an annual production of 113,500 lbs.; that pure gossypol-acetic acid can be produced at a cost of \$3.80 per pound at an annual production of 100,200 lbs.; and that pure gossypol will cost \$5.55 per pound at an annual production of 81,000 lbs. By marketing the phosphatides instead of returning them to the gums, the cost of producing pure gossypol will be \$3.91 per pound at an annual production of 81,000 lbs. These costs were estimated by assuming that Phase I of the process would be accomplished simultaneously with oil mill-extraction operations, and Phases II and III during remainder of the season.

It is readily apparent that gossypol or gossypol-acetic acid as produced are not inexpensive chemicals and would probably have to be produced for specialized uses, such as pharmaceuticals and the like, where the cost of these chemicals would not be prohibitive. Should product evaluation research now under way establish specific uses for gossypol and its intermediates, a demand for sizeable quantities of these materials might result.

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[Received April 13, 1959]

Report of the Uniform Methods Committee, 1958-59

THE MEETING of the Uniform Methods Committee was held at 2 p.m., April 20, in the Baronne room of the Roosevelt Hotel. The meeting was attended by six of the seven members of the committee. E. M. Sallee, our editor of Methods, was present as a member *ex officio*. Guests present were J. R. Mays Jr., V. C. Mehlenbacher, T. F. Waters, R. C. Stillman, J. C. Harris, W. T. Coleman, W. E. Link, and Harry Smith Jr. The last two were representing the Statistical Committee. The following matters were discussed, and the indicated decisions were made:

1. Fat Analysis Committee, V. C. Mehlenbacher, chairman

a) *Congeal Point. Tentative Method Cc 14-59.*
This new method was proposed for adoption as Tentative. Data on its precision and drawings of the cooling baths will be supplied. With minor additions, relative to type of burner and size of sample, the method is recommended for adoption as Tentative. *Adopted.*

b) *Viscosity of Transparent Liquids by Bubble Time Method. Tentative Method Ka 6-59.*
This new method is proposed as a replacement for present Official Method Ka 6–55 (revised April, 1956). The method has been carefully checked by the drying oils subcommittee under its chairman, K. E. Holt, and is judged much superior to our present Official Method. The Uniform Methods Committee commends Mr. Holt and his subcommittee for the excellence of its work. Precision data will be added. This method is recommended for adoption, as Tentative, to replace present Ka 6–55. *Adopted.*

c) *Acetone Insoluble Matter (in Lecithin). Tentative Method Ja 4-46 (revised May, 1957).*
Advancement of this Tentative Method to Official status is proposed by the subcommittee on analysis of lecithin, T. C. Smith, chairman. The Fat Analysis Committee has approved, and the Uniform Methods Committee recommends that this action be taken. *Adopted.*

d) *Fat Stability—Active Oxygen Method. Tentative Method Cd 12-57.*
A change in the end-point from a peroxide value of 125 milliequivalents to 100 milliequivalents is proposed, also several changes of a minor nature in the air-purification train, A. Apparatus. 3. These changes have been agreed upon by the Fat Analysis Committee and are recommended for adoption. *Adopted.*

e) *Titer Test. Tentative Method L 6a-55.*
The subcommittee on analysis of commercial fatty acids,