

# Crude Glycerol Glucoside Esters of Cottonseed Oil: Preliminary Cost Analysis

K.M. DECOSSAS, R.O. FEUGE, J.L. WHITE, SR., and L.W. MAZZENO, JR., Southern Regional Research Center, Science and Education Administration, U.S. Department of Agriculture, New Orleans, Louisiana 70179

## ABSTRACT

Glycerol glucoside esters prepared by transglycosylation of starch and glycerol, followed by interesterification with esters of cottonseed oil fatty acids, are well suited for use in the steadily growing food emulsifier market. They offer formulators and processors a wide range of compositions and physical properties for achieving more effective emulsification without increase in cost. Process flowsheets, capital costs, manufacturing costs, and general expenses are given for the production of 5.7 million pounds and 17.2 million pounds of crude glycerol glucoside esters annually in hypothetical 4-ton batch and 12-ton batch grass-roots plants, respectively. A material balance and preliminary plant layout for the 12-ton batch plant are also provided. The cost of crude esters ranges from 37.4 cents to 43.7 cents/lb, indicating that the crude esters would be competitive with many commercially available food emulsifiers. The process can be carried out in conventional batch process equipment without production of polluting by-products. Fixed capital investment for a new 12-ton batch plant would be \$2.5 million, and for a new 4-ton plant, \$1.3 million.

Feuge, White and Brown (3-7) recently prepared, examined, and reported on a number of glycerol glucoside ester products having potential to compete with many food emulsifiers now being marketed such as the sodium and calcium stearoyl-2-lactylates, phosphatides, anhydrosorbitol esters, polyglycerol esters, acetylated tartaric acid esters of monoglycerides, sucrose esters, and monoglycerides. The glycerol glucoside esters can be about 150 times more surface active than the monoglycerides and are, therefore, far less expensive on an end use basis, even though the monoglycerides may be cheaper on a unit weight basis. While glycerol glucoside esters have not been cleared for food use, they should prove to be acceptable food components. They are closely related to the important glycolipids of wheat flour and to those of all photosynthesizing plants.

This paper includes a preliminary cost analysis for producing sixty 4-ton batches and sixty 12-ton batches of crude glycerol glucoside esters monthly in hypothetical grass-roots plants. The cost analysis is considered preliminary because it is based on chemical laboratory data without any engineering pilot plant data. It was developed from experimental data by Feuge et al. and includes fixed capital investment, manufacturing costs, and general expenses.

## INTRODUCTION

Of the 4.4 billion pounds of surface-active agents produced annually in the United States (1), approximately 200 million pounds are consumed domestically as food emulsifiers, a market that is projected to grow at an annual rate of 6% through 1980 (2).

## PROCESS

Crude glycerol glucoside esters are prepared from cornstarch, glycerol, and partially hydrogenated cottonseed oil (IV 70) by the one-pot method developed by Feuge et al. (4). Figure 1 illustrates the sequence of processing operations and conditions occurring during production of the crude esters in the reactor of a hypothetical plant. Proces-

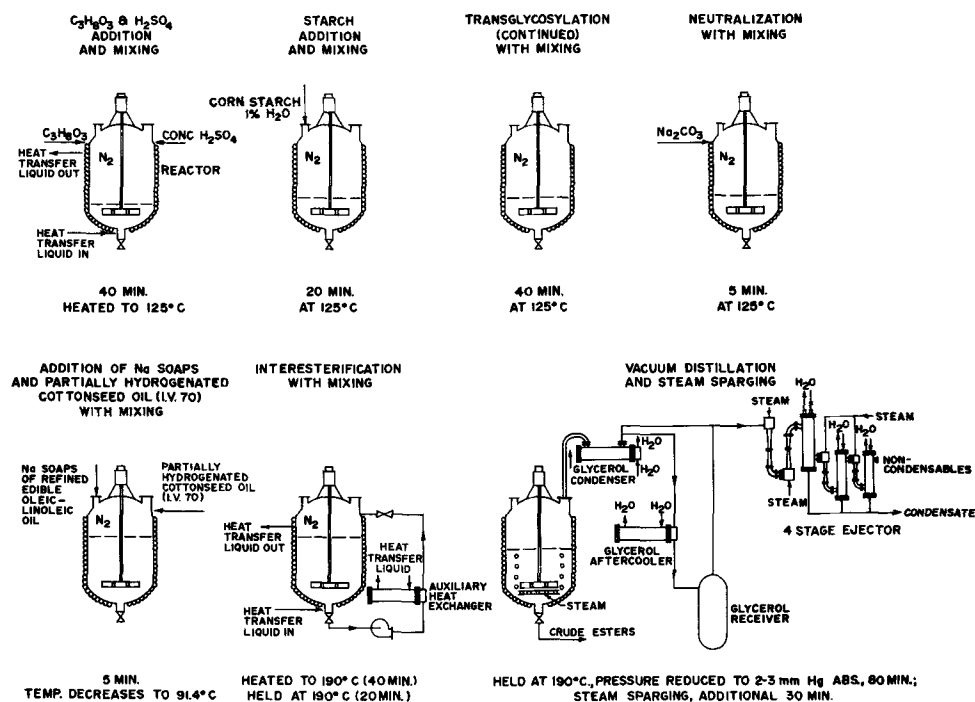


FIG. 1. Batch production of crude glycerol glucoside esters.

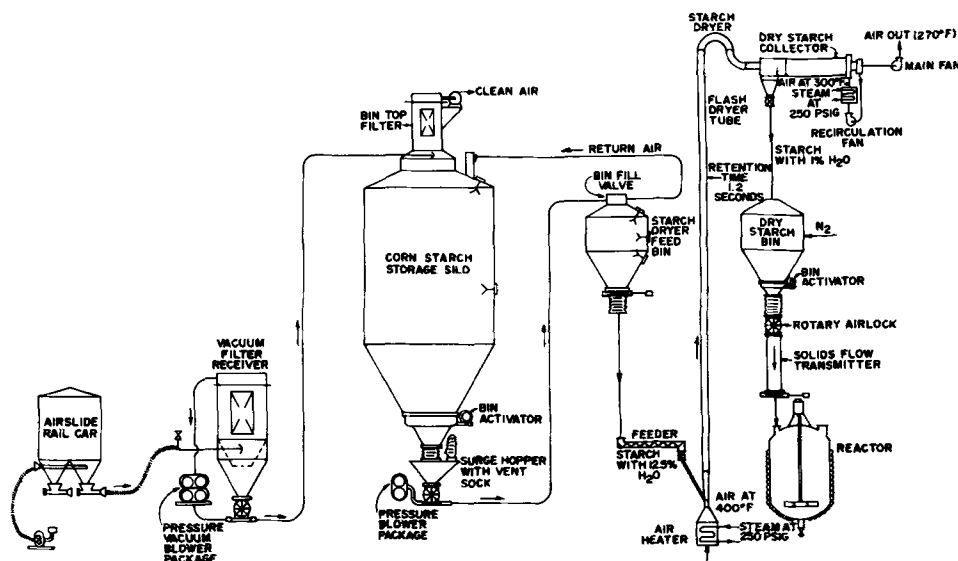


FIG. 2. Flowsheet for cornstarch receiving, storage, and drying systems.

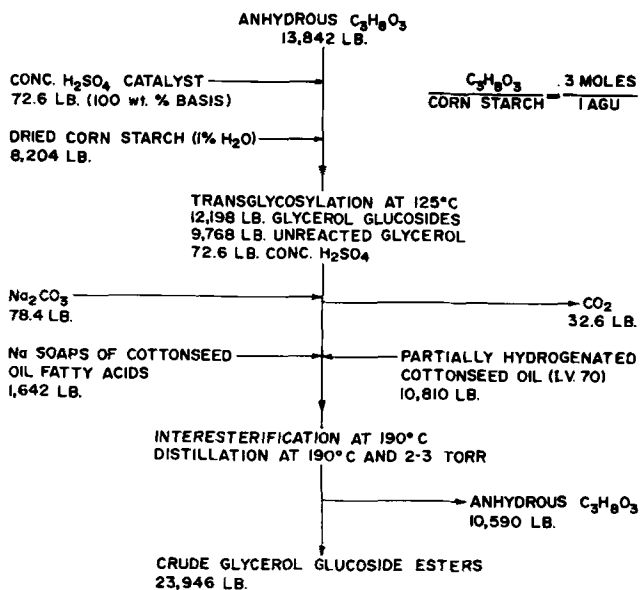


FIG. 3. Material balance: 12-ton batch.

sing in the reactor lasts 4 hr 40 min, enabling production of a batch during each 8-hr shift. Cornstarch, received in bulk at a moisture of 9.5% to 12.5%, is dried to 1% moisture or less (Fig. 2), before it is added to the reactor. Because of the potential danger of explosion when working with dry starch, the starch dryer system is equipped with an explosion suppression system that has ability to stifle an incipient explosion in a small fraction of a second and shut down all electrical control circuits. In addition, the electrical system is explosion-proof. Drying of the starch is necessary because moisture slows the reaction of starch and glycerol, reduces completeness of the reaction, and promotes formation of gels.

Sugars from various sources, including materials containing waste sugars, can be used in the process instead of starch, with variations in temperature, catalyst, and equipment size. Preliminary work has been done by White (J.L. White, unpublished data, 1975) using blackstrap molasses and other sugar sources.

## MATERIAL BALANCE

The material balance (Fig. 3) is for production of a 12-ton batch of crude glycerol glucoside esters.

The following weight relationships exist among the inputs of the hypothetical plants:

For each anhydroglucose unit (AGU) of dried cornstarch, 3 moles of anhydrous glycerol are used because at lower ratios AGUs tend to attach at various locations onto the glycerol glucoside molecules. The glycerol glucosides produced with 3 moles per AGU are 80% mono- and 20% diglucosides.

Concentrated sulfuric acid catalyst (100 wt % basis) equals 0.33% of the sum of the weights of cornstarch and glycerol.

Soaps input equals 5% of the sum of the weights of glucosides, unreacted glycerol, sulfuric acid, and partially hydrogenated cottonseed oil.

Cottonseed oil input is sufficient to provide 0.75 equivalent of fatty acid per AGU.

The crude product consists mostly of glycerol glucoside esters (yields of purified esters have been as high as 83.52 wt %), some free glycerol glucosides, sodium soaps, salts from neutralization of sulfuric acid with soda ash, possibly some unreacted fat (glycerides), and some free fatty acids. At room temperature, the product is not quite as hard as beeswax and has a viscosity about equal to SAE 90 lubricating oil. At 190 C, the temperature of interesterification, it is a thick liquid, pours, and can be splashed, and its viscosity is about equal to that of SAE 40 lubricating oil at room temperature. The crude esters have a specific gravity of 1.12, although some have had gravities less than 1.

Purification of the crude product made from cornstarch is unnecessary for many uses. However, if esters are produced from materials containing waste sugars, purification is necessary to separate the esters from other fractions associated with the waste sugars.

## PLANTS

The plants include process and storage equipment, piping, insulation, instrumentation and controls, electrical installations, service facilities, process and service buildings, land and yard improvements, as listed for the 12-ton batch plant in Table I. The process building (Fig. 4) accommo-

TABLE I  
Crude Glycerol Glucoside Esters Plant  
Fixed Capital Investment  
(Batch Size: 12 Tons of Product)

	All systems (\$)	Cornstarch system <sup>a</sup> (\$)	Esters system <sup>b</sup> (\$)	Service facilities (\$)	Proration <sup>c</sup> of service facilities between		Esters system (\$)	Cornstarch system plus its proration of service facilities (\$)	Esters system (\$)
					Cornstarch system (\$)	Esters system (\$)			
<b>Direct costs</b>									
a) Purchased cost of process and storage equipment <sup>d</sup>	475,200	188,470	286,730					188,470	286,730
b) Installed cost of process and storage equipment <sup>d</sup>	614,610	264,830	349,780					264,830	349,780
c) Process piping <sup>e</sup>	170,080	9,850	160,230					9,850	160,230
d) Insulation	31,350	5,540	25,810					5,540	25,810
e) Instrumentation and controls <sup>f</sup>	24,730		24,730						24,730
f) Electrical equipment and materials <sup>g</sup>									
<b>Service facilities (installed)</b>									
g) N <sub>2</sub> generating system	51,940			51,940					51,940
h) Steam boiler and auxiliaries	47,190			47,190					47,190
i) Heat transfer liquid system	177,200			177,200					177,200
j) Cooling tower and auxiliaries	24,340			24,340					24,340
k) Electric substation	33,130			33,130					33,130
l) Subtotal service facilities	333,800			333,800					333,800
m) Outside lines	30,730	13,240	17,490					13,240	17,490
n) Direct equipment costs, b) through e) + l) + m)	1,205,300	293,460	578,040	333,800				383,210	822,090
<b>Buildings (including services)</b>									
o) Process building	503,940	178,380	325,560					178,380	325,560
p) Boiler house	2,255			2,255				1,580	675
q) N <sub>2</sub> generating system house	2,255			2,255				1,690	565
r) Land and yard improvements	87,910	34,860	53,050					34,860	53,050
s) Direct costs, n) through r)	1,801,660	506,700	956,650	338,310				599,720	1,201,940
<b>Indirect costs</b>									
t) Engineering and supervision	173,010	50,670	95,660					50,670	95,660
u) Construction	173,010	50,670	95,660	26,680				5,530	21,150
v) Contingencies	239,330	70,090	132,330	26,680				5,530	21,150
w) Contractors fee	77,860	22,800	43,050	36,910				7,650	29,260
x) Indirect costs, t) through w)	663,210	194,230	366,700	102,280				21,200	81,080
y) Fixed capital investment, s) + x)	2,464,870	700,930	1,323,350	440,590				114,220	326,370
<b>Total</b>								815,150	1,649,720

a) Cornstarch receiving, storage, drying, and transfer equipment.  
 b) All process and storage equipment except cornstarch equipment.  
 c) In proportion to relative use of service facilities by these two systems.  
 d) Includes motors and most instrumentation.  
 e) Process and utility piping associated with the process equipment and storage tanks; located within the process building and the area of the storage tank aggregate.  
 f) Instrumentation and controls not included in a).  
 g) Distributed among costs of process and storage equipment, service facilities, outside lines, and buildings.

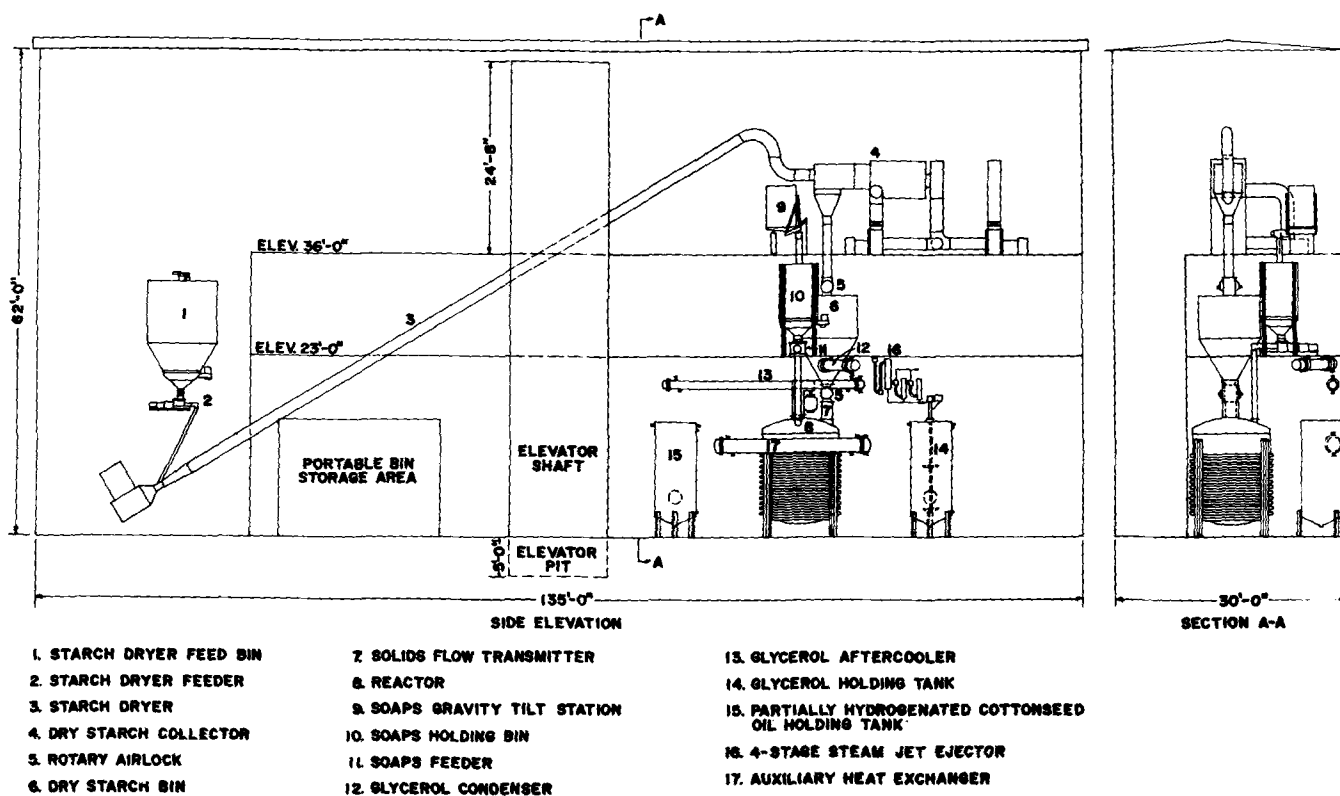


FIG. 4. Plant layout: elevations.

dates an equipment arrangement that makes maximum use of gravity flow to conserve energy.

An engineering prospectus for the 12-ton batch glycerol glucoside esters plant, including a detailed equipment list with specifications and costs, is available upon request from K.M. Decossas at the Southern Regional Research Center, USDA, PO Box 19687, New Orleans, LA 70179.

### FIXED CAPITAL INVESTMENT

Purchased equipment costs for the 12-ton batch plant (Table I) were obtained from manufacturers and are for the 4th Quarter 1975, when the Marshall and Swift equipment cost index was 450.6 (1926 = 100). Process building costs were obtained from building fabricators and are for the 1st Quarter 1976, when the Austin Company building cost index was 193 (1967 = 100).

Fixed capital investment for a plant for producing crude glycerol glycoside esters at the rate of sixty 12-ton batches/month (equivalent to three 8-hr shifts/day, 20 day/month) totals \$2.5 million (Table I). Approximately one-third of that amount, or \$815,150, is for the cornstarch system.

A plant for producing sixty 4-ton batches/month has an estimated fixed capital investment of \$1.3 million.

### MANUFACTURING COSTS AND GENERAL EXPENSES

Manufacturing costs and general expenses are summarized in Table II. For all practical purposes they are for the 1st Quarter 1976, except for electricity costs which are based on fuel adjustments for July 1974, the latest rates available at the time the cost analysis was prepared.

#### Raw Materials

Cost of raw materials is the largest single cost item, accounting for 64% to 75% of product cost.

To assure production of food emulsifiers of high quality, raw materials meeting the following specifications were

used in the cost study:

*Anhyd C<sub>3</sub>H<sub>8</sub>O<sub>3</sub>*: Nat, refd, USP, CP, 99.5%; or syn, USP, 99.5%. (Food grade anhyd C<sub>3</sub>H<sub>8</sub>O<sub>3</sub> was used).

*Conc H<sub>2</sub>SO<sub>4</sub>*: 66° Ba, 93% or higher.

*Cornstarch (C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>)<sub>x</sub>*: Refd, powd, unmodified, pure food starch; ca. 9.5% to 12.5% H<sub>2</sub>O when purchased; 98% to 99.5% through 200 mesh sieve.

*Na<sub>2</sub>CO<sub>3</sub>*: Food grade, powd or fine granulated.

*Partially hydrogenated cottonseed oil (IV 70)*: Refd, bleached, partly hydrogenated, deodorized cottonseed oil having an IV of 70 and a Solid Fat Index of about 18 at 70 F, as determined by AOCS Method 10-57.

*Na soaps of refd edible oleic-linoleic oil*: Made from any refd edible oleic-linoleic oil such as prime, once-refined cottonseed oil or rerefined cottonseed oil (bleaching and hydrogenation not necessary); partially hydrogenated soybean oil; palm oil; peanut oil; but no animal fats. No FFA, not more than 1% free alkali, not more than 5% H<sub>2</sub>O. Chemically pure with the following exceptions: If impurities such as the sterols and sterol esters are present in the edible natural oil from which the soaps are derived, then these impurities are permitted in the soaps; and if made by direct saponification of edible oil, it is all right to leave the glycerol produced in the product. Powder or chips would be satisfactory.

*N<sub>2</sub> gas*: 20 ppm CO<sub>2</sub>, 0.1-0.5% CO, 0.1-0.5% H<sub>2</sub>, 120 ppm (max.) O<sub>2</sub>, dew point -80 F at 85 psig, remainder N<sub>2</sub> and A.

#### Operating Labor

Hourly wage rates specified in footnote<sup>b</sup> of Table II were paid by a national vegetable oil refiner during the 1st Quarter 1976. The number of operators is based on a schedule of operations that allows approximately 2 hr for general preparation, 4 hr 40 min for the esters process cycle in the reactor (Fig. 1), and the remainder of the shift for product storage and/or packaging, and plant cleanup.

TABLE II

Crude Glycerol Glucoside Esters of Fatty Acids  
Manufacturing Costs and General Expenses  
(Production Rate: 60 batches/mo)

Total product cost	4-Ton batch (\$/batch)	12-Ton batch (\$/batch)
<b>A. Manufacturing costs</b>		
<b>(1) Direct production costs</b>		
a) Raw materials <sup>a</sup>	2,230	6,692
b) Operating labor <sup>b</sup>	177	177
c) Direct supervisory and clerical labor	27	27
d) Maintenance and repairs	104	201
e) Operating supplies	16	30
f) Utilities		
Electricity	6	15
Water	1	4
Steam	10	29
Natural gas	11	32
g) Laboratory charges	27	27
h) Subtotal, direct production costs (cents/lb)	2,609 (32.7)	7,234 (30.2)
<b>(2) Fixed charges</b>		
i) Depreciation	78	153
j) Property taxes	43	84
k) Insurance	17	34
l) Subtotal, fixed charges (cents/lb)	138 (1.7)	271 (1.1)
<b>(3) Plant overhead costs</b>		
m) Subtotal, plant overhead costs (cents/lb)	185 (2.3)	243 (1.0)
n) Total manufacturing costs <sup>c</sup> (cents/lb)	2,932 (36.7)	7,748 (32.3)
<b>B. General expenses</b>		
o) Administrative costs	89	89
p) Distribution and marketing costs	146	387
q) Research and development costs	59	155
r) Financing cost	261	585
s) Subtotal, general expenses (cents/lb)	555 (7.0)	1,216 (5.1)
<b>Total product cost</b> (cents/lb)	<b>3,487</b> <b>(43.7)</b>	<b>8,964</b> <b>(37.4)</b>
<b>Working capital</b> (\$)	<b>839,000</b>	<b>2,264,000</b>

<sup>a</sup>Excludes N<sub>2</sub> cost which is generated at plant site. N<sub>2</sub> cost is included among labor, utilities, fixed, and other manufacturing costs.

<sup>b</sup>One reactor operator at \$6.00/hr, one starch system operator at \$6.00/hr, one pump man at \$5.90/hr, and one forklift operator (half time) at \$5.75/hr. Includes base wage plus cost of living adjustment as stipulated in labor contract.

<sup>c</sup>h) + l) + m).

### Utilities

The thermal liquid must supply 10.3 million BTU (excluding heat losses) to the reaction mixture of each 12-ton batch. Maximum heating demand occurs when a batch is heated from 91.4 C to 190 C in 40 min during interesterification; on the basis of laboratory data, an estimated 6.0 to 7.1 million BTU/hr would be required for a 12-ton batch. About 85% would be needed for raising the temperature of the reaction mixture, and the remainder for fusion of partially hydrogenated cottonseed oil and for solution of the soaps in the oil. The heat of interesterification is only slightly endothermic under process conditions and has been disregarded.

### REFERENCES

1. U.S. Intern. Trade Comm., "Synthetic Organic Chemicals: United States Production and Sales, 1975," USITC Pub. 804, pp. 153-157, Washington, DC, 1977.
2. Stutz, R.L., A.J. Del Vecchio, and R.J. Tenney, Food Prod. Develop. 7(8):52, 54, 56-57, 60 (1973).
3. Brown, M., J.L. White, and R.O. Feuge, JAOCS 51:287A (1974).
4. Feuge, R.O., J.L. White, and M. Brown, submitted to JAOCS; abstract in JAOCS 49:88A-89A (1972).
5. Feuge, R.O., M. Brown, and J.L. White, Ibid. 49:672 (1972).
6. Feuge, R.O., J.L. White, and M. Brown, Ibid. 52:121A (1975).
7. White, J.L., M. Brown, and R.O. Feuge, Ibid. 50:306A (1973).

[Received October 12, 1977]