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PROCESSING the SOYBEAN

O. R. Sweeney
L. K. Arnold

WITHDRAWN

BULLETIN 103 (Revised)
ENGINEERING EXTENSION SERVICE
IOWA STATE COLLEGE AMES, IOWA

THE purpose of this bulletin, which was first published in 1929, is to present information, particularly from an engineering standpoint, on the practicability of soybean oil production in the American Corn Belt, with special reference to the state of Iowa. While it is necessary to discuss the growing of the crop, this phase of the work has been gleaned from the books, bulletins, and the publications referred to in the text, and should in no wise be accepted on the authority of the writers of this bulletin.

Publications of the Iowa Agricultural Experiment Station have been freely consulted, especially Bulletin 309, *Soybeans in Iowa Farming,* by Albert Mighell, H. D. Hughes, and F. S. Wilkins; Bulletin 234, *Soybean Hay for Fattening Lambs;* Bulletin 204, *Soybeans as a Home Grown Supplement for Dairy Cows,* by R. C. McCandlish, E. Weaver, and L. A. Lunde; and circular 84, *Soybeans,* by H. D. Hughes and F. S. Wilkins. Much assistance was secured through private communication from H. D. Hughes, Professor of Farm Crops; F. S. Wilkins, Assistant in Farm Crops; and C. L. Holmes, formerly Professor of Agricultural Economics.

Much of the information in the original manuscript was compiled by J. H. Arnold, then Research Fellow of the Engineering Experiment Station. The research studies carried out in the Chemical Engineering laboratories were under the direction of the faculty of that department, particularly F. C. Vilbrandt, formerly Professor of Chemical Engineering, and H. A. Webber, Associate Professor of Chemical Engineering.

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Processing the Soybean

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The Soybean and the Farm Problem

Characteristics of the Soybean

The soybean is an annual legume native to eastern Asia, where it has formed an important source of protein food for many centuries. As shown in Table 1, soybeans are composed of oil, protein, water, mineral matter, fiber, and carbohydrates. Soybean meal refers to the ground bean from which the oil has been expressed or extracted. Soybean flour is made by grinding the meal. The oil is valuable as a linseed oil substitute as well as for other uses. The meal is a high grade stock food.

TABLE 1. SOYBEAN ANALYSES.

Oil* %	Protein %	Water %	Fiber %	Ash %	Carbo-hydrate %	No. of varieties	Reference
20.35	35.40	7.70	4.60	5.79	26.16	7	(24)
18.91	37.83	10.23	5.23	4.44	23.46	16	(32)
18.73	33.88	13.48	4.52	4.37	24.05	14	(32)
19.00	35.40	9.60	5.00	4.80	26.20	—	(32)
20.04	34.99	7.74	4.52	5.79	26.57	6	(27)

*An average of 151 samples gives 20.75 per cent. (38).

Soybeans, like corn, are found principally in temperate regions. Early, medium, and late varieties are available for use in the various regions of the United States. They will thrive on almost all types of soil. Inoculation with nitrogen-fixing bacteria is necessary for satisfactory results, but the soybean bacteria are quite hardy, and thrive even in acid soils. Practically all of the agricultural experiment stations have issued bulletins dealing with the details of soybean cultivation.

TABLE 2. USES OF THE SOYBEAN.‡

- Soybeans
  - Plants
    - Green manure
    - Forage
      - Hay
      - Ensilage
      - Soiling
    - Pasture
  - Seeds
    - Meal
      - Human food
        - Breakfast foods
        - Diabetic foods
        - Flour
          - Bread
          - Cakes
          - Muffins
          - Biscuit
        - Infant foods
        - Macaroni
        - Crackers
        - Milk
      - Stock feed
      - Fertilizer
    - Oil
      - Glycerine
      - Explosives
      - Enamels
      - Varnish
      - Food products
        - Butter substitute
        - Lard substitutes
        - Edible oils
        - Salad oils
      - Waterproof goods
      - Linoleum
      - Paints
      - Soap Stock
        - Soft soaps
        - Hard soaps
      - Celluloid
      - Rubber substitute
      - Printing inks
      - Lighting
      - Lubricating
    - Food products
      - Dried beans
        - Soy sauce
        - Boiled beans
        - Baked beans
        - Soups
        - Coffee substitute
        - Roasted beans
        - Vegetable milk
          - Cheese
            - Fresh
            - Dried
            - Smoked
            - Fermented
          - Condensed
          - Fresh milk
          - Confections
          - Casein
        - Breakfast foods
      - Green beans
        - Green vegetables
        - Canned
        - Salads

Uses of the Soybean

The soybean has many uses as shown by Table 2 (27).* A vegetable milk (toniu) is prepared by boiling the meal in water about a half hour and filtering off the residue (41). Soybean curd (tofu) is prepared by coagulation of the solids in the milk. Soybean cheese (miso) is made by fermenting the proteins precipitated from the milk.

Because of the almost entire absence of starch from soybean carbohydrate, soybean flour has been developed as a diabetic food. The ready digestibility and high nutritional value of soybean flour have resulted in its use in such products as bread, rolls, muffins, cookies, doughnuts, sausages, pancake flour, macaroni, noodles, and dog food.

In addition to their high nutritional value, soybeans and soybean products produce beneficial dietary effects caused probably by either their lecithin or vitamin content. However, the soybean oil causes soft flabby flesh when fed in any considerable quantity as has been shown in hog feeding studies.

The amount of oil which can be fed with the beneficial results exceeding the undesirable ones from flabby flesh has not been determined by biological chemists. However, as is pointed out later, soy-

‡From "The Soybean." By Piper and Morse, McGraw-Hill, 1923.
*See references following text with corresponding number. This holds true for all numbers in parenthesis thruout bulletin.

TABLE 3. COMPOSITION OF SOYBEAN AND OTHER FLOURS.†

Flour and Meal	Constituents					
	Water %	Ash %	Fat %	Fiber %	Protein %	Carbohydrates %
Soybeans‡	6.14	5.24	20.71	1.72	39.56	26.63
Soybean**	6.10	6.20	4.50	2.05	47.30	33.85
Wheat	12.00	0.45	1.00	0.20	11.00	77.35
Corn meal	10.00	0.90	2.70	0.80	8.50	77.10
Rye	9.00	1.10	1.50	0.65	12.00	75.85
Graham	9.60	1.80	2.20	1.90	12.60	71.90
Whole wheat	10.90	1.05	2.00	1.00	12.00	73.05
Soybean flour*	7.65	6.08	20.38	1.63	40.65	21.93

†From Piper and Morse: The Soybean, McGraw-Hill.
‡From whole bean.
**From Soybean Cake analysis by Bur. of Chem. U. S. D. A.
*By E. Kupelwieser quoted by Horvath (21).

bean oil meal is an excellent hog food, free from the soft pork effect. The use of soybean flour in the human diet has given very satisfactory results.

Because of the high lecithin content of properly prepared soybean flour, it is being used where the emulsifying action of the lecithin is valuable, as in ice cream, in chocolate malted milk mixtures and chocolate candy.

Lecithin is a complex fatty material containing phosphorous and nitrogen. It is soluble in oils, fats, and alcohol but forms a colloidal solution in water. It is found in association with oils and fats of both animal and vegetable origin. The largest source of lecithin of animal origin is probably egg yolk which contains 7 to 10 percent. Soybeans contain from 1.5 to 2.0 percent lecithin. Lecithin has been made from egg yolk as a pharmaceutical preparation for the treatment of such diseases as tuberculosis, neurasthenia, chlorosis, scrofula, and rickets. The lecithin from egg yolk is expensive. It has been estimated (20) that a pound of soybean flour contains the equivalent of $25.00 worth of egg lecithin. The emulsifying action of lecithin has been used in Europe in margarine manufacture. It is possible to extract the lecithin from the beans with the oil by a mixture of benzol and alcohol from which the lecithin may be separated by blowing in steam. Flour made from whole beans or expressed meal contains the lecithin. In making the flour it is necessary to heat the beans to a temperature high enough to destroy the enzymes present to prevent the flour from having a rancid and "beany" taste.

The whole beans are usable as a food when baked, boiled, or roasted. The roasted beans are used as a coffee substitute. The green beans may be used as green vegetables or in salads. A soy sauce is prepared in China by fermenting a soybean-wheat mixture by rather crude empirical methods. A similar product is now being produced in the United States by modern factory methods using strict bacteriological control.

In a research study on possible edible forms of soybeans, in the chemical engineering laboratories at Iowa State College, Holt (17) found that beans soaked 18 to 24 hours in salted water could be cooked in hot grease to give a palatable product similar to salted peanuts. The best processing temperature was found to be 170° C. It was necessary to have sufficient hot fat to prevent the temperature from dropping more than 20° C. Beans roasted without soaking were hard and unpalatable.

Nelson (25) found that by heating soybeans in fat at 100° C. for five minutes, roasting at 160° C. for 20 minutes, and grinding fine, a product was formed which, when mixed with soybean oil, resembled peanut butter. The addition of salt improved the flavor. A mixture of one-half soybean butter and one-half peanut butter resembled peanut butter very closely.

Fairall (11) made a very palatable breakfast food from soybeans as follows: Whole soybeans were heated in fat at 100° to 110° C. for five minutes and then centrifuged to remove the fat. They were then split in an attrition mill and the hulls removed. They were then crushed to a size which would pass a 14-mesh screen and be retained on a 28-mesh screen. To each pound of soybeans was added one ounce of saturated salt solution and two ounces of saturated sugar solution and the whole stirred. The mixture was spread out in shallow pans about one-quarter inch to one-half inch deep and baked about one hour at 160° C. or until a satisfactory brown color developed. Fairall recommends that this food be served with cream and sugar.

Soybean casein, like milk casein, can be used to make a waterproof glue. Large quantities of soybean glue are reported as being used in the production of plywood on the Pacific Coast. It is also used for laminating insulating board.

In addition to use as a glue, casein is used as a sizing material for paper; as a textile water-proofing material; and as a paint medium.

Zenor and Tillson (42), in the chemical laboratories at Iowa State College, studied the production of adhesive materials from soybean meal. They ground soybean meal in a ball mill with water, using one pound of meal to one gallon of water, centrifuged the suspension in a super-centrifuge, and evaporated the solution to a syrupy consistency. The solution contained all of the water-soluble proteins and carbohydrates. The residue containing proteins, glycinin, phaseolin, insoluble carbohydrates, arabans, galactans, and fiber, was then treated with one percent sodium hydroxide solution and centrifuged, leaving a residue of fiber and galactans. This residue was hydrolyzed by refluxing with nitric acid and filtered. The filtrate contained mucic acid. The solution, after treatment with caustic soda, was treated with one percent hydrochloric acid solution to precipitate the proteins which were filtered out and dried. The solution containing the arabans was evaporated to a syrup. The adhesives thus produced were used to paste together strips of paper which were then tested in a tension testing machine of the type used for testing paper and textiles. The results are summarized in Table 4.

TABLE 4. BREAKING STRENGTHS OF SOYBEAN ADHESIVES.

Adhesive Substance	Breaking strength lbs. per sq. in.
Arabans	59*
Arabans	41
Soluble carbohydrates	45*
Soluble carbohydrates	59
Mucic Acid	42†
Casein	54

*Paper, instead of joint, tore.
†Joint slipped.

Plastics are made by treating soybean casein with formaldehyde. Considerable work has been done in the chemical engineering laboratories by Campbell (7) on the substitution of furfural for the formaldehyde. These casein plastics are being used in the production of buttons and various automobile knobs and small parts.

Dailey (9) working in the chemical engineering laboratories at Iowa State College concluded that it was not feasible to make a plastic direct from soybean-meal by dissolving the casein out with dilute sodium hydroxide and precipitating it with acetic acid.

Later, Forster (15) in the same laboratory, found that a plastic could be produced direct from extracted soybean meal by kneading with one cubic centimeter of 10 percent sodium hydroxide per gram of meal. No filler is necessary with this type plastic. Dailey found that a plastic could be made by heating extracted soybean meal with phenol, caustic soda, and paraformaldehyde at 115° to 125° C. for 12 to 15 minutes and molding at 135° to 145° C.

Soybeans in Iowa

The production of soybeans in Iowa has increased to a point where extensive uses other than seed will be required to warrant further increases. It is estimated from assessor's reports that about 1,004,000 acres were planted to soybeans in Iowa in 1935 of which it is expected that 250,000 acres will be harvested for seed. (24) A large production of soybeans is desirable for the following reasons:

(A) Soybeans are a more profitable crop than oats, and should, therefore, largely displace oats in corn rotations, especially in poorer oat-producing sections.

(B) Soybeans, like other legumes, add nitrogen to the soil and leave the soil in excellent condition for the following corn crop.

(C) Soybeans may be grown to excellent advantage in soils too acid for such legumes as alfalfa, sweet clover, and red clover.

(D) The oilmeal obtained, when the oil is removed from the

TABLE 5. COST OF GROWING SOYBEANS.

Item	Cost
Labor 6.4 hours at 20 cents	$ 1.28
Horse labor 13.9 hours at 7 cents	.97
Equipment	1.57
Manure, as for corn	2.44
General expense and overhead	1.20
Threshing, 25 bushels at 6 cents	1.50
Twine	.10
Building charges	.50
Land charges	5.00
Seed—2 bushels at $1.00	2.00
Total cost per acre	$16.56
Cost per bushel with 25 bushel yield	$0.66
Cost per bushel with 20 bushel yield	$0.83

beans, offers a highly satisfactory solution to the high protein feed problem confronting the stock farmer.

(E) The establishment of oil mills in rural communities is a desirable industrial development.

The culture of soybeans, which is similar to that of corn, is given in detail in various state agricultural bulletins, such as Bulletin 309 of the Iowa Agricultural Station, *Soybeans in Iowa Farming* (23), which gives details of best growing and harvesting methods with comparative costs. Costs vary, but the cost under present Iowa conditions is estimated in Table 5 which is based on data from Prof. John A. Hopkins of Iowa State College revised to present costs from data in Bulletin 309.

With a yield of 20 bushels per acre soybeans would have to be sold for about $1.10 a bushel to return the same profit as corn. This is well within the price of $1.63 a bushel, which, as is subsequently shown, can be paid by the oil mills. At the latter price a yield of only 10.1 bushels is necessary to break even with the growing cost of $16.56 an acre. Even with this low yield and return, soybeans would be a more satisfactory crop than oats which are produced at a loss. While the actual yields of soybeans grown on a large scale is at present an unsettled question, it is believed that under good conditions a yield of at least 20 bushels an acre should be secured. Yield data from various experiment stations are given in Table 6.

It is not recommended that soybeans be substituted for corn in the Corn Belt but rather for oats as a crop to rotate with corn.

The Soybean and the Nitrogen Problem

Nitrogen is one of the essential plant foods. If nitrogenous fertilizers are not supplied in some way the nitrogen content of the soil will decrease gradually until the soil becomes unproductive. In spite of the fact that nitrogen exists in the atmosphere to the extent of 70,000,000 pounds above each acre (40), over $100,000,000 is

TABLE 6. YIELDS OF SOYBEAN SEED IN VARIOUS LOCALITIES.

Bushels per acre	Varieties tested	Years of test	Locality grown	Reference
14.93	20	6	Maryland	Agr. Exp. Sta. Bul. 277
15.22	—	5	Maryland	Agr. Exp. Sta. Bul. 201
18.96	—	—	Missouri	Agr. Exp. Sta. Bul. 172
11.34	9	1	Michigan	Agr. Exp. Sta. Bul. 227
17.03	44	2 to 11	Illinois	Agr. Exp. Sta. Bul. 198
25.55	57	1 to 5	Delaware	Agr. Exp. Sta. Bul. 96
21.57	32	4 to 8	Virginia	Agr. Exp. Sta. Bul. 235
19.52	13	7	Ohio	Agr. Exp. Sta. Bul. 384
21.73	21	12	Ohio	Agr. Exp. Sta. Bul. 384
18.54	11	1 to 12	Ohio	Agr. Exp. Sta. Bul. 384
16.40	7	2	Wisconsin	Agr. Exp. Sta. Bul. 375
14.20	13	3	Wisconsin	Agr. Exp. Sta. Bul. 375
16.36	5	5	Wisconsin	Agr. Exp. Sta. Bul. 375
18.02	12	3	Wisconsin	Agr. Exp. Sta. Bul. 375
21.00	6	2	Ohio	Agr. Exp. Sta. Bul. 237
23.37	13	2	Ohio	Agr. Exp. Sta. Bul. 237
24.04	5	2	Ohio	Agr. Exp. Sta. Bul. 237
22.54	10	4	Ohio	Agr. Exp. Sta. Bul. 237
22.86	24	2	Ohio	Agr. Exp. Sta. Bul. 237
26.24	6	1	Ohio	Agr. Exp. Sta. Bul. 237
24.9	3	8	Iowa	Agr. Exp. Sta. Bul. 309
29.3	5	4	Iowa	Agr. Exp. Sta. Bul. 309
26.9	7	3	Iowa	Agr. Exp. Sta. Bul. 309
29.7	10	2	Iowa	Agr. Exp. Sta. Bul. 309
24.3	4	5	Iowa	Agr. Exp. Sta. Bul. 309
22.8	6	4	Iowa	Agr. Exp. Sta. Bul. 309

spent annually in the United States for commercial fertilizers. The solution of the problem of nitrogenous material for fertilizers lies in the efficient utilization of atmospheric nitrogen fixation. Six or seven pounds (18) of nitrogen per acre per year are fixed in the air during electrical storms and washed down by the rain and snow. Certain soil bacteria such as Acetobacter are probably responsible for the accumulation of large amounts of available nitrogen in the soil. Organic matter is necessary for their development, but if present to such an extent as to render the soil acid it becomes harmful.

The growing of legumes is the easiest, cheapest, and most effective means of supplying the soil with nitrogen. The soybean is particularly efficient in removing large quentities of nitrogen from the air when growing on soil of low nitrogen centent. Unlike our two principal oil producing plants—cotton and flax—it does not rob the soil of nitrogen but replenishes the supply of it in the soil. The straw from the beans may be returned to the soil as a fertilizer, and the oil meal from the beans fed to the stock on the farm where the beans are grown. If the manure is returned to the soil eighty percent of the nitrogen, and nearly all of the phosphorous and potash, are replaced (41). As a result, a valuable oil has been produced, a high protein feed produced at low cost, and the nitrogen content of the soil increased to a point where the needs of a succeeding corn crop may be adequately met. Oats extract plant food from the soil, and are produced at an actual financial loss to the farmer.

TABLE 7. VALUE OF SOYBEAN MEAL AS A SUPPLEMENTAL FEED FOR HOGS.

Feeds used	Daily gain (lbs.)	Pounds feed necessary for 100 pound gain			Cost of extra corn**	Value of supplemental food as a corn replacement per ton†
		Corn	Supplement	Extra corn*		
Corn only	0.50	585.83	——	250.43	$ 3.118	——
Linseed meal	1.11	339.73	56.62	4.33	0.054	$ 108.00
Soybean meal	1.27	335.40	37.27	——	——	167.20††
Tankage	1.86	318.82	35.43	5.27	0.066	——
Soybean meal	1.67	315.52	39.44	1.97	0.025	——
Soybeans	1.40	313.55	65.32	——	——	——
Tankage	1.500	349.82	38.869	4.279	0.0535	——
Soybean meal	1.506	345.54	43.193	——	——	——
Soybeans	0.91	369.5	65.7‡	——	——	——
Tankage	1.00	385.2	31.0‡‡	15.7	——	——

* Corn required in excess of that required when soybean meal is used as a supplemental feed.
** Calculated at 70 cents per bushel. Tankage $60 a ton.
† Cost of extra corn divided by number of pounds supplemental food times 2000.
†† Value as replacement feed for linseed meal (linseed meal at $46 per ton) is $46/2000×56.62 − $0.054 = $1.357 for 37.27 lb. or $72.80 a ton.
‡ 13.4 pound mineral mixture at $14.33 a ton.
‡‡ 2.1 pound salt at $20.00 a ton.

The Soybean and the Protein Problem

One of the difficult problems confronting the stock farmer today is to secure low cost protein feed for balancing rations. The soybean, which has been an important source of protein food in China and Japan for many centuries, is the cheapest and most efficient producer of vegetable protein available to the farmer. The protein of the soybean is superior to other vegetable proteins in common use because, unlike them, it contains the proper amounts of amino acids necessary for biological efficiency as a food.

In spite of this suitability of the soybean protein the bean itself is not a desirable hog feed to use in quantity. The large amount of oil in the beans may cause both digestive disturbances and soft pork. Soft pork brings a lower price than the normal product and therefore is undesirable from the producer's standpoint. The obvious remedy is to remove most of the oil and feed the resulting meal. This gives a food of higher protein content which has been shown by various experiments (16) (31), to be superior to the soybeans and to linseed meal. The superiority of the soybean meal as a corn supplement in feeding hogs is shown in Table 7. The value of $72.80 a ton for soybean meal in comparison with linseed meal shows the soybean meal to be the cheaper of the two since it commonly sells at about $40.00 a ton. The other tests give it an average value of $56.00 a ton compared with the soybeans at $36.73 a ton, or $1.10 a bushel. Other tests give the soybean meal from a ton of beans as worth more than the ton of beans itself for feeding purposes. The comparative nutrient values are given in Table 8.

TABLE 8. NUTRIENT VALUE OF COMMON STOCK FEEDS.**

	Digestible nutrients (percent)				Nutritive ratio	Total protein %
	Protein	Fat	Carbohydrates	Total		
Soybean meal (12)						
Solvent*	41.9	0.9	31.2	75.1	0.793	46.0
Pressure†	39.8	5.5	29.6	81.8	1.054	43.8
Tankage (60%)	56.2	7.2	——	71.4	0.3	60.4
Fish meal	40.1	8.3	——	58.8	0.5	51.4
Cottonseed meal	37.0	8.6	21.8	78.2	1.1	44.1
Gluten meal	30.2	4.4	43.9	84.0	1.8	35.5
Soybeans	33.2	16.1	24.7	94.1	1.8	36.5
Linseed meal	30.2	6.7	32.6	77.9	1.6	33.9
Wheat bran	12.5	3.0	41.6	60.9	3.9	16.0
Middlings	13.4	4.3	46.2	69.3	4.2	17.4
Oats	9.7	3.8	52.1	70.4	6.3	12.4
Corn, shelled	7.5	4.6	67.8	85.7	10.4	10.1
Cowpea hay	13.1	1.0	33.7	47.8	2.7	——
Soybean hay	11.7	1.2	39.2	51.1	3.6	——
Alfalfa hay	10.6	0.9	39.0	50.5	3.9	——
Crimson clover hay	9.7	1.0	36.8	47.5	4.0	——

*Extraction method.
†Hydraulic-press method.
**Henry, W. A., and Morrison, F. B., Feeds and Feeding, Henry-Morrison Co., 1922., Appendix p. 13.

The Soybean and the Vegetable Oil Problem

The World War made it apparent that the United States is no longer independent of foreign sources of vegetable oil supply. While, normally, considerable quantities of oils are imported, wartime importations reached enormous values, and served to draw attention to the importance of developing further the American vegetable oil industry. Our post-war industrial development has emphasized the need for vegetable oils, which are important raw materials in numerous industrial chemical processes. Paints, edible fats and oils and soaps are the principal products manufactured from crude vegetable oils, while hundreds of lesser uses can be enumerated. Linseed oil, the principal paint and varnish oil is produced from flaxseed. Much of the seed used by American mills is imported from the Argentine, Russia and India; present annual importations amounting to about a half-billion pounds of seed, corresponding to about 150,000,000 pounds of linseed oil, or 37 per cent the total production.

Although the demand for linseed oil is steadily increasing, it is unlikely that there will be much increase in the American acreage planted to flax, since the plant is notorious as a soil robber, and hence is not favored by farmers except on virgin soil. Future increased demands will undoubtedly be met by increased importation of Argentine flaxseed, thereby not only making the United States dependent on a foreign country for an important source of oil, but also removing a large amount of money from the country which could well be retained here through increased domestic production of oilbearing seeds. The cultivation of the tung tree, from which China wood oil—a valuable paint oil—is derived, on several large Florida plantations, is a step in this direction. Increasing the production of soybean oil will also relieve the impending shortage of linseed oil to a large extent, although, because of its lower drying power it probably cannot displace linseed oil entirely. Varnish made from soybean oil is abnormally flexible and bakes to a very hard finish. Soybean oil enamels are superior to those made from linseed oil or tung oil (37), since they undergo less yellowing with age. When "blown" at 500° F. for several hours, soybean oil thickens to a consistency desirable for making baking japans, and when heated to 500° F. for a few minutes, it bleaches more permanently and to a greater degree than linseed oil.

Experimental work by Enemark (10) shows that the production of linoleum from soybean oil instead of linseed oil should not be difficult for a linoleum expert. In his experimental work he obtained no visible signs of oxidation from mechanical agitation or aeration for 24 hours with manganese borate, lead linoleate, cobalt linoleate, and linoleic acid at 25° to 50° C. When the temperature was raised to 275° to 290° C. for from 4 to 6 hours both mechanical stirring and aeration gave brown gummy material. When soybean oil containing these driers was allowed to flow down over muslin sheets a good coat of oxidized oil was accumulated on the cloth. The cobalt linoleate gave the best drying action. The oxidized oil was scraped from the cloth and heated to fusion (150° C.) when 12 percent melted rosin and an equal amount of kauri gum were added. To this mixture was added filler. Three fillers were used: ground cork, 3⅛ pounds to one pound of the cement; wood flour, 3½ pounds to one pound of cement; and finely ground corn cobs, 3½ pounds to one pound of cement. The mixture was pressed in a heated hydraulic press. The material with cork filler gave a very promising material, that with corn cob filler not so good, and that with wood flour a rather brittle product. Soybean oil may also be used in printing inks.

In the Orient, soybean oil has been used as an edible oil for centuries. American margarine manufacturers have found it to be a satisfactory substitute for cottonseed oil in the preparation of butter substitutes. The supply of American grown cottonseed appears to remain about constant, the 1933 production being very nearly the same as for 1912, without much variation during the intervening years. The inroads of the boll weevil, together with the increasing tendency of the southern farmer toward diversified farming, indicates that in the future a decrease rather than an increase in the amount of American grown cottonseed is to be expected. Increased demands must therefore be supplied by increased importation or domestic production of other oils. Coconut oil imports, for example, increased fivefold between 1912 and 1925 and have increased slightly since then. Peanut oil and soybean oil are to be looked to as the

TABLE 9. EFFECT OF FILTRATION WITH VARIOUS DECOLORIZERS ON THE COLOR OF SOYBEAN OIL. (26)

No.	Filtering material	Percent Material	Temperature during Agitation °F	Time of Agitation Min.	Tintometer Reading	
					Red	Yellow
1	Fullers Earth	15	202	15	1.0	16.0
2	Fullers Earth	10	221	15	1.0	25.0
3	Fullers Earth	10	302	5	1.0	13.0
4	Fullers Earth	10	221	5	1.0	23.0
5	Fullers Earth	10	221**	5	1.0	25.0
6	Fullers Earth*	10	248	5	1.0	12.0
7	Kieselguhr	15	221	15	—	—
8	Bentonite	10	248	5	1.0	14.0
9	Bone Black	15	212	5	1.0	14.0
10	Filchar	15	212	5	1.0	21.0
11	Special Carbon	15	212	5	1.0	31.0
12	Corncob Char	10	248	5	1.0	31.0
13	Calcined Cob Char	10	248	5	1.0	11.0
14	Calcined Cob Char	10	248	5	1.0	27.0
15	Peat (ground)	10	248	5	1.0	39.0
16	Peat Char	10	248	5	1.0	10.0
17	Peat Ash	10	248	5	1.0	10.0
18	Peat Ash	15	248	5	—	4.0
19	Peat Ash	20	248	5	—	3.0
20	Peat (ground)	10	248	5	1.0	21.0
21	Peat Char	10	248	5	1.0	31.0
22	Peat Ash	10	248	5	1.0	21.0
Not filtered					2.5	70.0

*Treated with hot hydrochloric acid and calcined.
**Filtered at 32°F.

most promising substitutes for cottonseed oil which can be produced in the United States.

Oils to be used for edible purposes require refining to remove rancidity, undesirable odor or taste, and frequently to improve the color. Agitation of the oil with a small amount of caustic soda solution is usually all that is required to remove the rancidity. Odor, taste, and color can frequently be improved by filtering the oil through various absorbent materials. Peirce (26) working in the chemical engineering laboratories studied the effect of filtering soybean oil through fuller's earth, kieselguhr, bentonite, bone black, cob charcoal, and peat ash (Table 9). His procedure was to agitate the oil with 10 to 20 percent of the decolorizing material for 5 to 15 minutes at temperatures ranging from 212° to 302°F. and then filter. The color of the oil was determined before and after filtering by a tintometer in terms of red and yellow intensities. The greatest reduction in color was secured by the use of peat ash. The color was improved by the materials tried. Repeated filtration with fuller's earth and peat ash gave better results than a single filtration (Table 10), two filtrations giving practically a colorless oil. Exposure of the oil to ultra violet light from

TABLE 10. EFFECT OF REPEATED FILTRATION WITH FULLERS EARTH AND PEAT ASH ON COLOR OF SOYBEAN OIL. (26)

No.	No. of times filtered	Method	TintometerReadings		
			Yellow	Red	Blue
a	0		70	2.5	3
	1	4	23	1.0	—
	2	4	4	0.5	—
	3	4	1.5	—	—
	4	4	1.5	—	—
b	1	3	14	1.0	—
	2	3	2.5	—	—
	3	3	1.5	—	—
	4	3	1.5	—	—
c	1	2	25	1.0	—
	2	4	3.5	0.5	—
d	1	3	23	0.5	—
	2	3	9	—	—
	3	3	2	—	—
	4	3	1	—	—
e	1	6	18	1.0	—
	2	6	3	0.5	—
	3	6	1.5	—	—
	4	6	1.0	—	—
f	1	19	4	—	—
	2	19	1.5	—	—
	3	19	1.5	—	—

NOTE: No. (a) to (e) incl. Fullers earth; No. (f) peat ash.
The numbers under "Method" refer to conditions given in Table 9.

both sunlight and a mercury vapor lamp produced a high degree of bleaching (Table 11). Attempts by Peirce (26) to bleach soybean oil with chemicals were not as promising as the treatment with ultra-violet light and the filtration. Bleaching powder bleached fairly well; chlorine darkened the oil; and potassium dichromate had little effect. Boric acid and hydrogen peroxide had slight bleaching action.

One method of deodorizing which is used considerably in such oils as cottonseed is steam distillation. This method was tried on soybean oil by Becker and Ahrens (4). Oil treated first with caustic soda was distilled at 149° F. under 25 inches vacuum, giving after 8 hours of distillation an oil with no objectionable odor and practically the same color as originally. Untreated oil under similar conditions came to the same odor in 5 hours. Distillation at 212° F. produced a darker oil with less satisfactory odor reduction. The best results were secured on untreated oil distilled at 85° C. and 25 inches vacuum. Under these conditions the odor was reduced to an insignificant amount in 2.5 hours.

Heating raw soybean oil to high temperatures darkens it considerably and intensifies the beany odor, thus making it undesirable as an edible oil. Luebke (22) found that treatment with caustic soda to remove the free fatty acids, followed by filtration through fuller's

TABLE 11. EFFECT OF ULTRA-VIOLET LIGHT ON THE COLOR OF SOYBEAN OIL (26)

Source of Ultra-violet	Oil used	Time of Exposure Hours	Tintometer Readings	
			Yellow	Red
Sunlight	Original	0	70*	2.5
		12	7	1.0
		30	0.5	0.1
		42	0.5	0.1
Sunlight	Bleached	0	1.0	—
		12	0.5	—
		30	0.4	—
		42	0.4	—
Mercury vapor Lamp†	Original	0	70*	2.5
		1	7	1
		2	2	
Mercury vapor Lamp†	Bleached	0	1	—
		1	1	—

*Also: Blue 3.0.
†Quartz tube mercury lamp at distance of 10 cm.

earth, gave an oil which could be heated to 225°C. for a short time without darkening. He found a ten percent caustic treatment gave best results. After standing for 24 hours to settle the foots formed, the oil was heated for ten minutes to remove moisture. After cooling, five percent fuller's earth was added with continuous stirring and the oil filtered. The oil was then heated to 225°C. for 20 minutes which bleached it considerably. It still had an undesirable odor which was partially removed by bubbling carbon dioxide through it. This refining required for each hundred pounds of oil one pound sodium hydroxide, ten pounds fuller's earth, and 26 pounds of carbon dioxide, costing about $1.66. During the refining there was also a ten percent loss of oil, most of which would be recoverable as soap stock.

Data by Almond (2) indicated that best results in steam distillation are secured with 20 inches of mercury and a temperature of 217°F and with oil previously treated with caustic soda. Almond checked his original data secured in glassware by larger scale equipment using two-gallon batches of oil.

Forman (14) studied the effect of activated alumina and "Alorco" absorbent in removing odor from the oil. He was interested in removing undesirable odor without changing the coloring materially, since for certain purposes, such as oleomargarine manufacture, the natural colored oil is preferable. He found that much of the odor was removed by a preliminary vacuum steam distillation at 180°C. and 20 inches of mercury for two hours. Higher temperature and lower temperature destroyed more color. When alumina was shaken with oil thus treated and the mixture set aside for five weeks a considerable improvement in odor was noticeable. Steam distilled oil was filtered through activated alumina at 25° and 100°C. There was a decided deodorization with small amounts of removal of color, better results being secured at the lower temperature. Filtration of the crude oil through the Alorco absorbent produced decided decolorization and deodorization.

Burkett (6) treated the oil with sulfuric acid after treating with caustic soda. He then steam-distilled the oil using conditions found best by Forman. The additional treatment with the acid gave very little improvement over Forman's method. A new method of treating the beans previous to expressing the oil, based on the rapid inactivation of the enzymes at high temperatures in the absence of oxygen (20), was also investigated by Burkett. The beans were heated for five minutes in vegetable shortening at 100°C., ground, and the oil expressed. The resulting oil was practically free from objectionable odor.

Large amounts of vegetable oils are consumed by the soap industry, with coconut oil and palm oil the principal ones at present. Twenty-five years ago cottonseed oil was used in greater amounts than these two, but during the war it lost its leadership, the amount dropping from 36.2 percent of the total in 1912 to only 2.2 percent in 1923 and to less than 1.0 percent in 1934. The consumption of coconut oil increased from 21.6 percent in 1912 to 54.5 percent in 1923 and to 60 percent in 1934, while that of palm oil rose from 2.1 in 1912 to 20.8 percent in 1923 and 27.2 percent in 1934. Palm oil is not dutiable, and most of the coconut oil comes from the Philippines and hence is not subject to tariff regulations. The net result of this replacement of cottonseed oil by palm oil and coconut oil has been that the American soap industry, instead of using an oil produced in this country, is now forced to import over three-fourths of its oil. It is quite probable that the increased use of coconut oil in butter substitutes may require that other oils be found to replace it as soap stock, for which it is becoming too high-priced. During 1917, to meet an inflated wartime demand for soap, soybean oil formed 19.5 percent of the oil used for soap stock. A prominent soap manufacturer has stated that soybean oil is quite suitable for this purpose, and, were a larger supply available, more of it would undoubtedly be used. For hard soaps it is necessary to mix soybean oil with tallow or other hard fats. Alone, it is rather difficult to saponify completely, but when mixed with other oils it can be handled readily. According to Horvath (19) a caustic soda solution greater than 8.5° Baume should not be used with pure soybean oil although a higher concentration may be used in mixtures of the oil with other fats. He recommends soybean oil soaps as particularly suitable for use with hard and salt waters. Soft soaps similar to those from linseed oil can be made from soybean oil.

Blair (5) working in the chemical engineering laboratories at Iowa State College studied the variation in lathering power of soybean oil soap made with varying percentages of sodium hydroxide and potas-

TABLE 12. UNITED STATES VEGETABLE OIL PRODUCTION.*

Year	Linseed Oil lbs.	Cottonseed Oil lbs.	Soybean Oil lbs.	Total all oils lbs.
1914	406,669,000	1,789,777,000	2,764,000	2,338,185,000
1918	375,452,000	1,282,823,000	79,861,000	2,308,685,000
1922	456,514,418	934,627,442	751,108	1,834,380,750,
1926	720,109,940	1,760,529,592	2,645,514	2,930,909,422
1927	776,714,498	1,806,756,866	3,087,670	
1928	751,444,531	1,460,468,881	4,715,908	
1929	763,576,494	1,584,360,725	11,008,743	2,951,000,000
1930	516,326,277	1,616,101,513	14,387,460	2,719,000,000
1931	520,735,372	1,416,799,761	39,149,653	2,539,000,000
1932	326,569,465	1,571,048,918	39,445,464	2,380,000,000
1933	405,948,180	1,399,655,043	26,532,955	2,397,000,000

*U. S. Dept. Com. Bur. Census "Animal and Vegetable Fats and Oils" reports for 1927-1933.

sium hydroxide. The lathering test was made as follows: A solution of one gram of soap in 800 cubic centimeters of distilled water was made up. Twenty cubic centimeters of this solution were shaken 20 times in 10 seconds in a 50 cubic centimeter graduate. The result was read as the heighth of the lather. He found that a mixture of sodium hydroxide and potassium hydroxide gave a soap superior to sodium hydroxide alone and that 25 percent potassium hydroxide was nearly as effective as 100 percent. He found that the sodium soap of soybean oil lathers poorly but that its lathering power may be improved by the addition of other substances. Rosin increased the lathering power with optimum results at 10 percent of the weight of the oil. The most effective additions tried for increasing the lathering power of the sodium soap, were 20 percent lard or cocoanut oil and 40 percent triethanolamine or sodium silicate.

Softley (35) after experimental work on soybean oil soaps concluded that much better soap may be made from soybean oil which has been heated above 180°C for one-half hour than with the crude oil; soap from soybean oil lathers well but not as well as cocoanut oil soap; soap containing as high as 70 percent soybean oil soap is very satisfactory.

If a sufficient supply were available, domestic soybean oil could probably be substituted for the 150,000,000 pounds of linseed oil now imported, thus utilizing about 15,000,000 bushels or the product from 750,000 acres of land. About 100,000,000 pounds of tung oil are imported and if soybean oil were subsistuted for this, an additional 10,000,000 bushels of beans or the product of 500,000 acres would be required. Soybean oil can be substituted in part for the oils used in soap manufacture and as edible oils. The coconut and palm oils amount to over 600,000,000 pounds. The potential market for the soybean oil is thus about 850,000,000 pounds per year in excess of present production. This would correspond to about 85,000,000

TABLE 13. VEGETABLE OIL IMPORTS INTO UNITED STATES.*

Year	Coconut oil lbs.	Tung oil lbs.	Palm oil lbs.	Linseed oil lbs.	Soybean oil lbs.
1914	58,012,000	30,139,000	49,092,000	——	12,554,948
1920	216,327,103	67,962,150	41,948,224	35,200,199	112,213,750
1925	233,174,452	101,553,519	52,624,334	13,607,141	19,492,900
1927	293,369,704	89,650,411	159,911,079	944,432	14,914,792
1928	290,636,702	109,221,771	169,227,565	173,447	13,116,220
1929	411,936,213	119,677,718	261,816,442	9,960,961	19,489,129
1930	317,919,253	126,322,599	287,492,580	2,125,342	8,348,352
1931	325,174,560	79,311,155	258,144,609	235,492	4,916,253
1932	249,116,580	75,922,229	217,167,294	25,243	404,572
1933	316,078,135	118,759,963	287,482,836	11,257,148	3,669,048

*U. S. Dept. Com.. Bur. Census "Animal and Vegetable Fats and Oils," reports for 1927-1933.

bushels of beans if produced by the most efficient methods. This production would require, at 20 bushels to the acre, about 4,250,000 acres in addition to the present acreage.

Many uses for soybeans are undeveloped in America at present. The utilization which will actually take place in the future is dependent upon conditions which cannot be accurately determined.

Soybean oil has been destructively distilled to give products resembling petroleum. Satow (19) formed a calcium soap from the oil and destructively distilled it. He obtained about 20 percent light oil (under 150°C.); 60 percent middle oil (150°-300°C); 10 percent heavy "petroleum" (300-330°C); and about six percent residue oil. Forty gallons of soybean oil yielded about 28 gallons of the oils listed, 33 pounds glycerine, and 480 cubic feet of combustible gas.

Reid (29) in the chemical engineering laboratories at Iowa State College cracked soybean oil by heating it to 350°C with animal charcoal as a catalyst. The product as made in glass equipment was a pale yellow with a disagreeable odor. A run in metal equipment gave a product discolored by metallic salts. The product was distilled to

TABLE 14. IMPORTS AND EXPORTS OF SOYBEANS AND SOYBEAN OIL.*

Year	Imports of Soybeans lbs.	Imports of Soybean Oil lbs.	Exports of Soybean Oil lbs.
1914	1,929,435	12,554,948	——
1919	4,368,000	195,808,421	——
1925	3,811,897	19,492,900	519,668
1927	4,189,168	14,914,792	1,184,343
1928	4,255,734	13,116,220	852,307
1929	4,337,160	19,489,129	129,096
1930	3,851,796	8,348,352	517,009
1931	3,544,089	4,916,253	897,536
1932	2,550,941	404,572	45,722
1933	469,691	3,669,048	——

*Compiled from data in U. S. D. A. Yearbooks and U. S. Dept. Com. Bur. Census, "Animal and Vegetable Fats and Oils" reports for 1927-1933.

TABLE 15. CONSUMPTION OF SOYBEAN OIL BY INDUSTRIES IN THE UNITED STATES, 1934.*

(Quantities in thousands of pounds.)

Industry	Soybean oil used lb.	Total all oils and fats used
Compounds and vegetable shortenings	2,735	1,214,742
Oleomargarine	24	214,132
Other edible products	509	292,466
Soap	1,354	1,474,415
Paint and varnish	10,451	329,894
Linoleum and Oilcloth	2,843	67,811
Printing Inks	59	15,544
Misc. Products	2,109	259,143
Loss, includ ng foots	823	159,856
Total	20,907	4,028,003

*Bureau of Census Data quoted in: Anon. "Soapers Used More Fats in 1934". Soap XI, No. 4: 30-1 (April 1935).

give fractions having specific gravities from 0.7428 to 0.8635, viscosities from 69 to 187 seconds Saybolt, saponification numbers from 1.6 to 123, flash and fire tests ranging from 5° at room temperatures to 217° and 256°F. respectively. Coke containing 71 percent carbon remained behind.

Smith (34) as a result of similar studies obtained fractions of the following characteristics: specific gravity, 0.760 to 0.874; viscosity 37 to 185 seconds Saybolt; saponification number 1.0 to 112; flash and fire tests from 5° at room temperature to 215°C and 250°C. Alstrand (3) heated soybean oil in a reflux set-up with bone charcoal at 280°C. for 1.5 hours while bubbling hydrogen through it. The resulting oil resembled a medium grade lubricating oil, having the following properties: flash point, 383°F.; fire point, 433°F., pour point, 290°F.; specific gravity, 0.9315; saponification number 23.8; and Maumene number 47.

In Manchuria (19) blown soybean oil is mixed with a heavy petroleum product and used for greasing railway car axles. The untreated oil is used as a substitute for rape oil in railway signal lamps. A rubber substitute is made from soybean oil by treating it with nitric acid and ammonia. Another rubber substitute is made by treating the oil with sulfur chloride. Soybean oil is also made into a waterpoofing material for concrete.

Tables 13 and 14, showing the American imports and exports of soybean oil, emphasize its status as a utility oil, capable of supplying wartime needs effectively as a substitute for other oils. Under the stress of wartime demands, imports of soybean oil in 1918 were over thirty times the 1913 imports, while from 1916 to 1920 great quantities of this oil were brought over from the Orient.

The tariff of 2.5 cents a pound applied in 1921 and increased to 3.5 cents in 1930 has materially reduced the imports. Since this tariff

TABLE 16. OIL CONTENT OF SOYBEANS.

Percent oil	Varieties (Number)	Reference
20.35	7	U. S. Dept. Agr., Bulletin 931
20.37	6	Tenn. Agr. Exp. Sta.
18.91	16	Satow, Researches on Soybean Oil Extraction
18.73	14	Satow, Researches on Soybean Oil Extraction
18.51	3	Maryland Exp. Sta. Bul. 277
20.44	50	North Dakota Agr. Exp. Sta. Bul. 118
17.01	1	Ohio Agr. Exp. Sta. Monthly Bul., 1923, p. 146
18.00	51	Delaware Agr. Exp. Sta. Bul. 96
18.07	51	Mississippi Agr. Exp. Sta. Bul. 227
18.38	2	Mississippi Agr. Exp. Sta. Bul. 235
17.12	23	Ohio Agr. Exp. Sta. Bul. 237
17.50	—	Henry and Morrison, Feeds and Feeding, Appendix
20.07	4	Piper and Morse, The Soybean, p. 126
19.63	30	Maryland Agr. Exp. Sta. Bul. 277

18.78% = Average of above.
18.00 has been taken as a fair figure on which to base the calculation of the sales return on oil.

went into effect there has been a steady increase in the amount of soybean oil produced in the United States. There is at present time a demand on the part of certain farm leaders for an increase in tariff on vegetable oils. Such an increase on linseed and tung oil might readily lead to practically no imports and their substitution by soybean oil. This is also true of the other oils with the exception of such oils as are imported duty free from the Philippines. In addition the increase in consumption of vegetable oils due to increase in population and other causes is a factor.

Methods of Producing Soybean Oil

The Hydraulic Press Method

Oil presses have been used in Manchuria for centuries to remove oil from the soybean. These presses are very crude affairs, and naturally are ineffcient. In recent years the development of the hydraulic press has produced apparatus which is capable of dealing with linseeds much more efficiently than the early hand- or wedge-press. In all cases the principles involved are the same; first, the preparation of the seed by grinding and cooking, with the object of rendering the oil more easily separable from the seed, and second, the forcing out of the oil from the ruptured oil-cells by the application of pressure.

The first step in milling soybeans is cleaning the seed. This ordinarily is not necessary, as the seed is usually quite free from foreign material when received, but if not, a seed cleaner should be used. The beans are broken up in a disk huller, which breaks each bean into several pieces and thus enables the crushing rolls to handle them more easily. From the huller the beans go to the rolls, which crush

them into very thin flakes, or fine meal. These rolls, in a ten-ton plant are arranged in a set of five, the top rolls being twelve inches in diameter, the bottom roll fourteen inches in diameter, and all rolls 24 inches long. The cracked beans from the disc huller are fed into a hopper at the top of the stand of rolls, and are distributed evenly over the surface of the top roll by a small corrugated roller at the bottom of the hopper. They are first ground between the top and second rolls. Then, deflected by a guide, the cracked beans pass between the second and third rolls, where the particles are crushed still finer. This continues until four crushings have occurred, the reduction in size being progressive. At this stage many of the oil cells have been broken, and the finely ground beans are ready to be cooked, to complete the rupturing of the oil cells and render the oil more mobile, as well as to coagulate the albumen and prevent its inclusion in the expressed oil.

A bucket conveyor delivers the crushed beans to the cookers which consist of steam-jacketed, relatively flat cylindrical chambers, one above the other, equipped with agitators. The diameter varies from 54 inches to 84 inches, and the number of chambers from one to five. A ten-ton plant uses either one or two chambers. The cooking temperature is about 180° F., the meal passing automatically through the various chambers, each chamber being discharged through gates into the chamber below, at intervals of about fifteen minutes. The moisture content is carefully controlled, by either introducing steam into the cookers or withdrawing steam by means of a small exhaust fan. The cooking operation is the most important part of the process for it is upon the condition of the seeds as they emerge from the cooker that the yield of oil depends. The moisture content, agitator speed, cooking time, and cooking temperature must be carefully regulated, as upon these factors the amount and quality of oil obtained depends. No set rules can be given, for this operation depends on the judgment of the operator who must be experienced.

The cooked meal is withdrawn from the cookers in batches of about twenty pounds, and passes to the cake former, which produces a compact cake that is easily inserted into the press box without breaking up. A camel's hair or wool press cloth of suitable size is first placed in the bottom of the meal box of the former; the meal from the cooker is charged into the box, on the top of the cloth. A pressing ram, operated by steam or hydraulic pressure, descends into the meal box, compressing the meal into a compact cake. The ends of the cloth are then folded over so as to enclose the cake. This cake is then transferred to the press on a steel sheet, and the process is repeated until the press is filled.

Each press holds about fifteen to twenty-five cakes about eleven inches by twenty-eight inches in size. The press itself consists of a base and a head of heavy cast iron, firmly bolted together by heavy

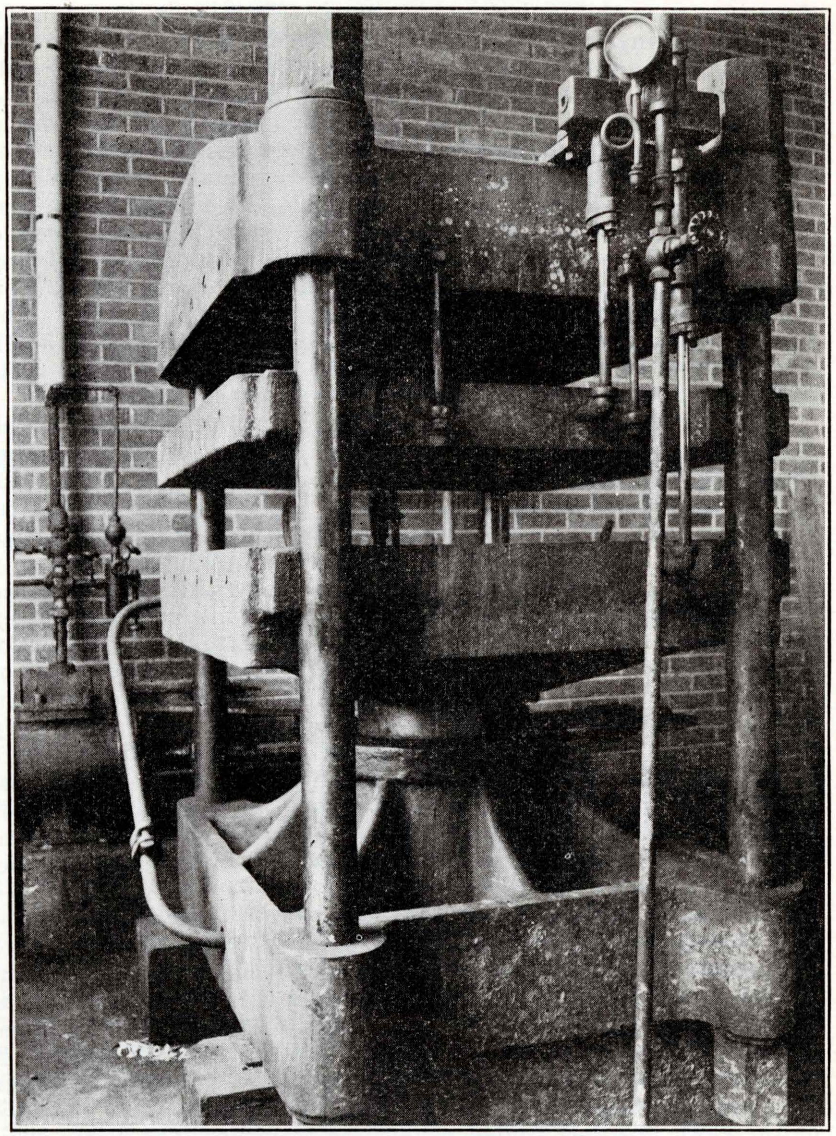

Fig. 1. Experimental Hydraulic Press.

steel columns. (See figure 1.) Compartments for holding the cakes are formed by a series of corrugated steel plates, one above the other, and so arranged as to be movable upward by the press ram when the press is filled, and resting on supports when the ram is with-

drawn. The ram is actuated by pressure transmitted from a cylinder in the base of the press, and travels upward, pressing the cakes against the head of the press. As the ram rises, its speed decreases, and the pressure increases. When a pressure of 500 pounds per square inch is reached, about half of the oil has been removed. At this point a change valve operates to change the press from the low-pressure line to the high pressure line, the latter being used for pressures up to 4000 pounds per square inch. The pump which produces the pressure usually has one piston for the low-pressure and another for the high-pressure line. The pressure transmission fluid is oil, preferably of the kind that is being produced. The oil exuding from the cake travels along the surface of the press plates until it reaches the outer edge when it flows off into a trough built around the outside of the press. The pressing is continued for about twenty to thirty minutes, depending on the condition of the seed. The cakes are then removed, after releasing the pressure, and the edges which contain an excess of oil are generally trimmed off and returned to the cookers. The trimmed cakes may be bagged as such, or else ground into meal. The oil from the press is run into a settling tank, where the particles of meal are allowed to settle out, after which it may be further purified by filtering.

A considerable amount of manual labor is required in filling the presses, as each cake must be removed from the former and inserted into the press box separately. Up to the forming operation, the process is practically automatic. Power is furnished from a line shaft operated by a single motor or steam engine. From this shaft the rolls, huller, cooker agitators, pump, cake formers, trimmers, conveyors, and elevators are operated.

The press cloths used to enclose the cakes are a source of considerable expense as they are costly and last for only a short time. The use of a box press instead of one with only plates reduces this item a great deal. Cage presses owing to their rather low efficiency of oil removal are unsuited for processing soybeans, otherwise the press cloths might be eliminated entirely.

The cake produced by the hydraulic pressure method contains about six percent of oil, corresponding to about 4.9 percent of the weight of the beans. This relatively low efficiency is the greatest drawback of the press method, since the raw material used averages initially about eighteen percent oil. Another disadvantage is that the meal is cooked in order to coagulate the albumen, which is thereby rendered less digestible and consequently less suitable as a stock feed. The oil is a hot-pressed oil, and will therefore break, or deposit mucilage, when heated to high temperatures. On this account, it is not so suitable for paint and varnish making as cold-pressed oil.

The investment required to equip a hydraulic press plant is low, being less than half that for an extraction plant and somewhat less than that for an expeller plant. The operating costs are intermediate between those of the other two types of plant.

The advantages of the hydraulic press type of mill are:

(A) A low investment cost, due to the simplicity and cheapness of the apparatus required.

(B) Low water requirements, since there are no solvents to vaporize, consequently no cooling water and but little steam consumption.

(C) An oil is produced which is more readily accepted by certain of the trade than extracted oil.

(D) There is no solvent loss, nor are there parts which wear down quickly and must be replaced.

(E) The capacity of the mill is readily increased by the addition of another press at small cost.

(F) Steam-raising costs are lower than for an extraction plant, and not a great deal higher than for an expeller installation.

(G) Insurance rates are much lower than for an extraction plant with its inflammable solvents, and there is no depreciation due to solvent corrosion.

The disadvantages of this type of mill are:

(A) The cake shows a high residual oil content, which represents a large monetary loss, and is also undesirable from the stockfeeding aspect.

(B) The albumen in the cake has been coagulated, and is consequently somewhat less digestible.

(C) Expensive and short-lived press-cloths are used.

(D) The power requirements are higher than by the extraction method.

The Anderson Expeller Method

The Anderson Expeller was developed to meet the need for oil-producing equipment which was continuous in its operation. The hydraulic press system, which is necessarily intermittent in action, possesses the disadvantages common to all discontinuous processes—mainly the large labor requirements and losses of time in charging and discharging the presses. The expeller, once started, requires very little attention, one man being able to care for several machines. (See Figure 2.)

The preliminary treatment of the beans involves drying and crushing. The moisture content, which is from seven to ten per cent in the undried beans must be reduced to about three percent before feeding to the expeller in order to obtain uniformly satisfactory results. Ordinarily, preliminary screening of the beans is unnecessary, as they are usually quite free from dirt and foreign bodies. The type of dryer frequently used is known as a grain dryer. It is made up of steel plates, pressed to the proper shape and riveted together in sections, which may be assembled to give any desired capacity. The beans are held in horizontal inclined steel shelves attached to vertical plates, the shelves are staggered so that the beans descend in a zigzag path, and are stopped at the bottom by mechanically operated slides. The zigzagging prevents packing and enables thorough drying to occur. The heating medium is hot air, which is drawn over steam pipes by a fan, and then passes through the perforated sides of the bean racks into the beans. The descent of the beans through the drying racks may be made either continuous or intermittent and the best operating conditions will be determined by the moisture content of the beans.

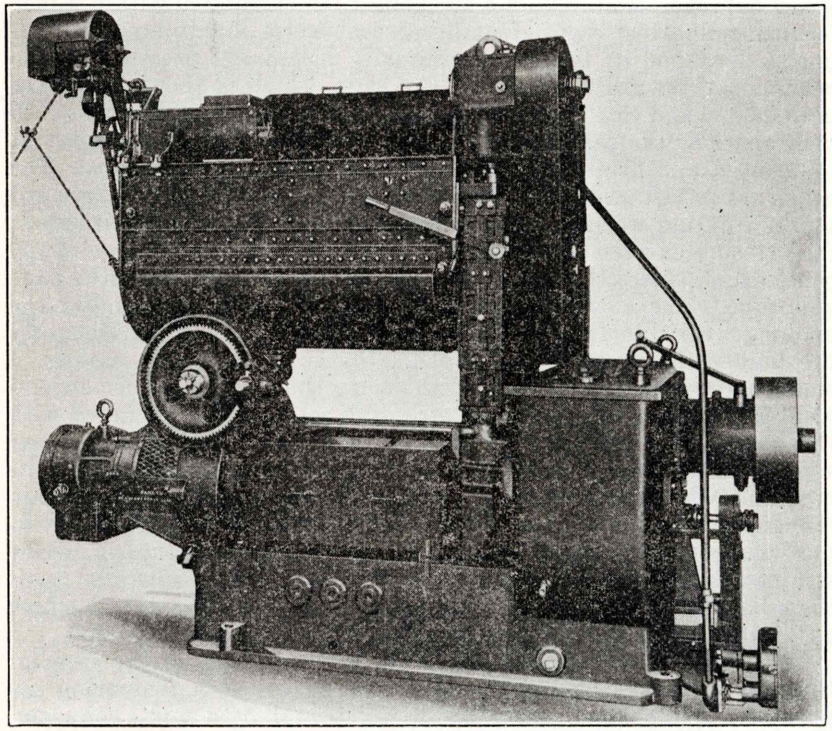

Fig. 2. An Oil Expeller.

The dried beans are ground by a roll crusher or a disc mill, to flake or tear the beans so as to break the outer skin and allow the oil to be expelled more easily. A large amount of fine material is not desirable, since it escapes from the expeller along with the oil and only makes subsequent purification more complicated. The object of the crushing should be to break up the oil cells and the outer skin, thus allowing the expeller to remove the oil easily. After crushing, it is desirable to pass the beans through a second dryer to further reduce the moisture content.

This second drier is preferably one of a rotary type with a scraper for preventing the sticky ground beans from forming a cake on the sides. For small plants a single drier of this type is preferable to two driers.

The expeller itself operates on a principle similar to that of a meat grinder. The beans are subjected to the end thrust of a powerful screw or worm, mounted on a steel shaft which rotates within a perforated cylindrical cage. Usually several worm flights are used, being so arranged as to give a gradually increasing pressure as the beans move toward the outlet. The cage, which is about six inches in diameter and thirty-six inches long, is built up of rods about 0.025 inch apart at the feed and discharge ends, and 0.015 inch apart at the center, and firmly held in place by steel hoops, or clamps. The beans are introduced at one end of the cage, and are carried forward by the rotating worm. At the outlet end, a conical stop is provided; the pressure exerted on the seeds is determined by the position of the cone, which varies the size of the annular opening between the cage and cone. The closer together the cone and cage the smaller the opening available for the discharge of the cake, and consequently the higher the pressure developed. In the more recent models, a choke arrangement has replaced the cone, thus giving a finer adjustment and eliminating the rotary grinding action which occurred with the cone. The ordinary working pressure is about six tons per square inch. The oil cake passes along the cage, emerging at the cone end, while the pressure exerted by the backing-up action within the cage forces most of the oil out of the beans and through the grating composing the cage. The oil is then pumped through a rotary strainer, which removes the meal particles and automatically feeds them back into the expeller. The cake emerges in thin sheets which are broken up on a revolving cake breaker at the discharge end.

The crushed seed is conveyed to the pressing cage of the expeller through a steam-jacketed trough which serves as a tempering apparatus. While being carried along this trough by a spiral conveyor, the crushed beans are heated to about 150 Deg. F. This treatment renders the oil more mobile, but does not cook the beans long enough to cause a separation of the mucilaginous matter or albumen, when heated to 500 Deg. F., and is therefore especially suited for the manufacture of varnishes. A superior quality cake is also obtained, since the digestibility of the nutrients is not impaired by the tempering.

Since the only steam requirement is for tempering the beans, the boiler capacity necessary is very small, a five horsepower boiler being ample for an expeller plant handling ten tons daily. This affords a considerable saving, both in initial and in operating costs. The amount of oil remaining in the cake is quite large, approximately six

percent, which of course represents a large loss, since the oil in the cake is sold at cake prices, or about eight cents a pound lower than oil prices. Settling tanks are not required as in the hydraulic press method, the oil being pumped directly to the storage.

The advantages of the expeller system over the others are:

(A) Low labor costs, due to the continuous operation.

(B) Low steam costs, since steam is not required for solvent distillation or for prolonged cooking.

(C) A cold-pressed, non-breaking oil, especially suited to paint and varnish manufacture, which shows a low refining loss.

(D) Very small water requirements, since little steam and no cooling water is necessary.

(E) No press cloths nor lost solvent to replace.

(F) A cake is produced which is highly digestible.

(G) The space requirements are very small, making expansion of the plant easy.

(H) A plant using a single expeller requires only a small investment.

(I) Many types of oleaginous materials may be pressed in the same expeller, making it possible to press corn germs, peanuts, tung nuts, cottonseed, linseed, etc., in the same plant.

Disadvantages of the expeller system:

(A) Large amount of oil left in cake.

(B) Larger power requirements than hydraulic press or extraction methods.

The Solvent Extraction System

In recent years a demand has arisen for a system of oil production capable of removing a higher percentage of the total oil from oil-bearing materials than is possible with expression methods. The oil cake produced by pressure methods contains from five to fifteen per cent of residual oil, which when sold at meal prices represents not only a financial loss but a decrease in the amount of oil available. With materials such as soybeans, which have comparatively low oil content, profitable operation becomes exceedingly difficult unless most of the oil can be removed. The overhead charges are practically the same no matter what the efficiency of the process may be. To meet this need, solvent extraction has been developed.

Three principal steps are involved in the treatment of oilbearing materials by this process; first, the preparation of the seed, consisting usually of cleaning and rolling; second, the treatment of the flaked seeds with the solvent, which dissolves out the oil; and finally, the separation of the oil from the solvent by distilling off the latter. The first and last steps are done in essentially the same way by all the systems of extraction now in use; the second step, however, admits of wide variations, both in machinery used and in method of treatment. The extraction plants proposed at present may be grouped into two divisions—those employing a stationary vertical cylinder as the extraction vessel, and those having a horizontal rotating drum. Stationary extractors are primarily a European development, being used quite extensively in France and England. The rotary extractor is the more popular in the United States, finding application in the treatment of packing-house wastes and similar refuse, as well as in the production of vegetable oils. Numerous advantages are claimed for each type over the other, but both have been found to be quite practical for the purpose, and nearly equal in installation and operating costs.

The reduction of the beans to the proper condition for extraction is preferably done by a set of rolls of large diameter. Experiment has shown that the largest yields of oil are obtained when the beans are flaked, rather than crushed to a powder, as is done when the hydraulic press system is used. The oil cells in a thin flake are readily reached by the solvent and such flakes have less tendency to pack and become inaccessible to the solvent than fine particles. In addition the separation of the extracted meal from the solvent oil solution is considerably easier, as there is less clogging of the filter screen. The optimum diameter for the rolls is about three feet, which as the beans are reduced more gradually results in a crushing rather than a grinding action, thus producing less fines. Other forms of mills, such as disc attrition mills, may of course be used, with somewhat less satisfactory results.

I. The Stationary Extractor. There are two principal types of stationary extractors in use; one is merely a large-scale Soxhlet continuous extractor, in which the solvent percolates through the extractor charge, and is periodically siphoned off into a still, from which it is returned to the extractor by distillation and condensation. The second type involves the use of superheated solvent vapor to aid in the extraction, while the mass of material in the extractor is stirred by an agitator, which also aids in discharging the extracted meal. Rotary extractors are all of the same general type, with minor variations in construction. The stirring of the charge is accomplished by slowly rotating the drum, into which the crushed seed and a suitable quantity of solvent are charged through suitable inlets, provision for heating being generally made in the form of a steam jacket.

A well known system of extraction makes use of two stationary vertical cylinders as extraction vessels, provided with under-driven agitators for stirring the material during the extraction process. The seed is charged into the extractors through manholes at the top, above which hoppers are placed to hold a charge of the seed delivered from the crushing rolls. Discharging is done with the aid of the agitators through doors in the side of the extractor near the bottom, the operation being performed almost automatically by the

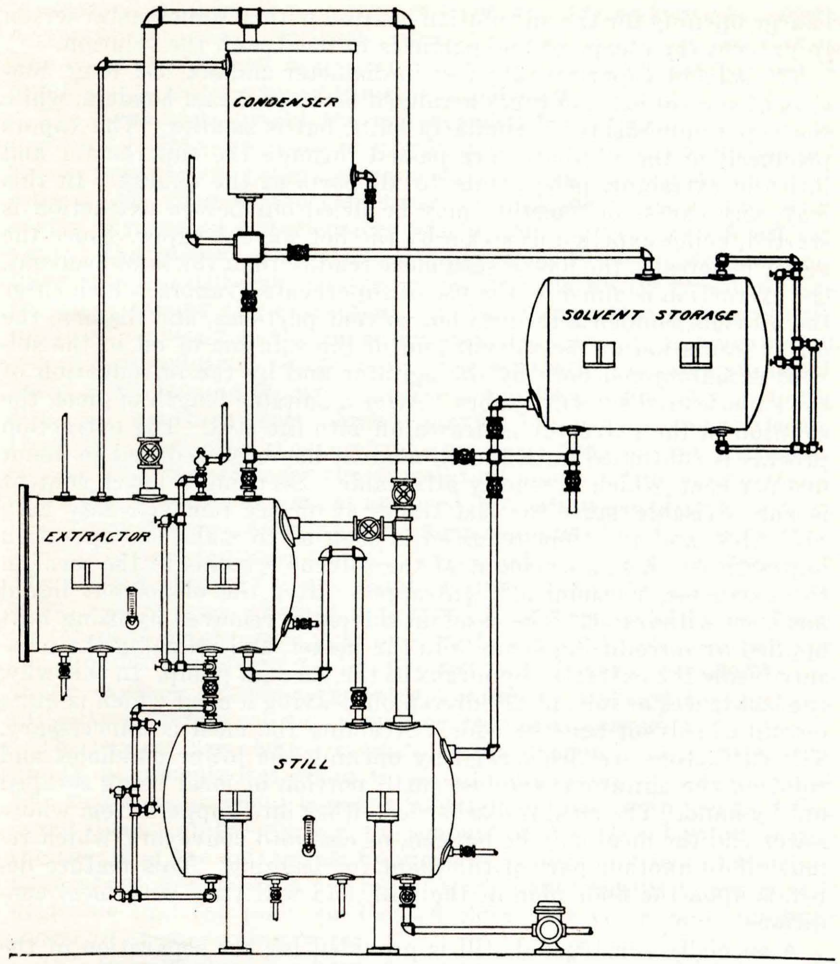

Fig. 3. A Stationary Solvent Extraction Plant.

agitators, but finished by hand. It is claimed that the stirrer method of agitation is more effective than the tumbling method such as is used in the rotary system, since less packing and balling up of the material results. The extractors, which are about six feet in diameter and ten feet deep, are equipped with steam jackets on the bottom and for about half the distance up the sides, for the purpose of warming the charge during extraction to make the oil more mobile and hasten the extraction process. Pipe lines are provided for the introduction and removal of the solvent and the oil solution, and the discharge opening for the oil solution is fitted with a Monel metal screen to prevent the escape of fine particles of meal with the solution.

The solvent vaporizer, 3½ feet in diameter and six feet long, consists of several heating tubes arranged between steam headers, while the vapor superheater is similarly built, but is smaller. The vapors produced in the vaporizer are passed through the superheater and into the extractor, penetrating to all parts of the charge. In this way, any excess of moisture may be dried out before extraction is started, being expelled as steam by the hot solvent vapor. Since the vapor penetrates the flaked seed more readily than the liquid solvent, the extraction is aided by the use of superheated vapors, which enter the oil cells, condense to form hot solvent particles, and dissolve the oil. Circulation of the solvent and of the solution of oil in the solvent is maintained both by the agitator and by the introduction of the superheated solvent vapors. After a suitable length of time, the solution in the extractor is drawn off into the still. The extraction process is continued until the oil content has been reduced to about one per cent, which is readily attainable. Securing a lower content is not advisable, since the last traces of oil are removed only with difficulty, and the time required is such as to make the operation impractical. A small amount of the solvent remains in the meal in the extractor, mechanically entrapped, after the oil-solvent liquid has been withdrawn. The residual solvent is removed by using heat applied by introducing steam into the jacket, and reducing the pressure inside the extractor by means of the vacuum pump. In this way, the last traces of solvent are driven off, leaving a meal which is quite devoid of solvent taste or odor. Steaming the meal is unnecessary. The extractors are discharged by opening the lower manholes and rotating the agitators; the last small portion of meal being scraped out by hand. The meal is discharged either into hoppers from whose lower end the meal may be bagged, or else into conveyors, which remove it to another part of the plant for bagging. This feature depends upon the floor plan of the mill, and will vary with local conditions.

A specially constructed still is provided for the separation of the solvent from the solution of the oil. This is a quite difficult matter, as the last traces of solvent are not easily removed by simple distillation, and their presence is readily detected by odor and taste. The presence of even small amounts of solvent in the oil lowers its value considerably, and on this account much prejudice against extracted oil has grown up. The early extraction plants did not produce a solvent-free oil, and, while this objection no longer holds true for the modern plants, the prejudice still remains. The purifying still is of a vertical tubular type, in the form of cast iron cylinders flanged at each end and joined together into a complete unit. Heat is applied through steam tubes in one of the cylinders. By means of a thorough heating accompanied by continuous circulation, the oil

is obtained completely free from solvent, and the solvent vapors are driven off into the condensers, where they are condensed for re-use. The oil thus obtained is the crude soybean oil of commerce, and is pumped into storage tanks to await shipment or refining.

The condensers are of the water-cooled type, two of them being provided. They are cast iron cylinders containing drawn copper tubes through which the hot vapors pass. The cooling water circulates in the shell of the condenser, around the tubes, counter-currently, the coolest water coming first in contact with the coolest solvent. The solvent condensate coming from these condensers contains some moisture, since more or less water is always removed from the seeds during the extraction. A water separator is accordingly provided to separate this moisture from the solvent, as otherwise it would accumulate in the solvent. The separator operates automatically, removing the the water and sending the purified solvent to the clean solvent tank, from which it may be pumped for use in the extractors. Two other storage tanks are provided, one for half spent solvent and the other for the oil solution being fed to the purifying still. Two charges of solvent are used in treating each batch of beans —the first charge dissolving out a large amount of oil in a short time, and the second reducing the oil content to the requisite one per cent. The second charge for one batch is drawn off into the half spent solvent tank, from which it is pumped to be used as the first charge on the next batch, since it is only partially saturated. In this way the amount of solvent to be distilled is reduced considerably. A single cylinder double-action steam pump is supplied for pumping the solvent and oil solution from one vessel to another.

The solvent loss, which is unavoidably encountered in extraction plants, is estimated at about three gallons per ton of seeds treated. The steam requirement is about 3000 pounds per ton of seeds. This is not drawn uniformly, but the amount varies considerably during the course of the extraction. Condensing water is quite an important item, about 3000 pounds per ton of seeds being required; hence, it is desirable that the plant be located close to a river, lake, or other source of cheap cooling water.

This type of plant has been shown to be easily adapted to soybean extraction.

II. The Large-scale Soxhlet Type Extractor. This extractor is primarily a French development, being used extensively in France and her colonial possessions. It is a modification of the well known Soxhlet extractor which is much used for laboratory extractions because of its automatic operation and its efficiency. The siphoning action of the Soxhlet, however, is displaced by a continuous flow of solvent through the extractor, so that the material is always covered with solvent. The extractors themselves are of the stationary type, two of them being necessary for a capacity of ten tons of beans per day. Each extractor consists of a large vertical cylinder, in the bot-

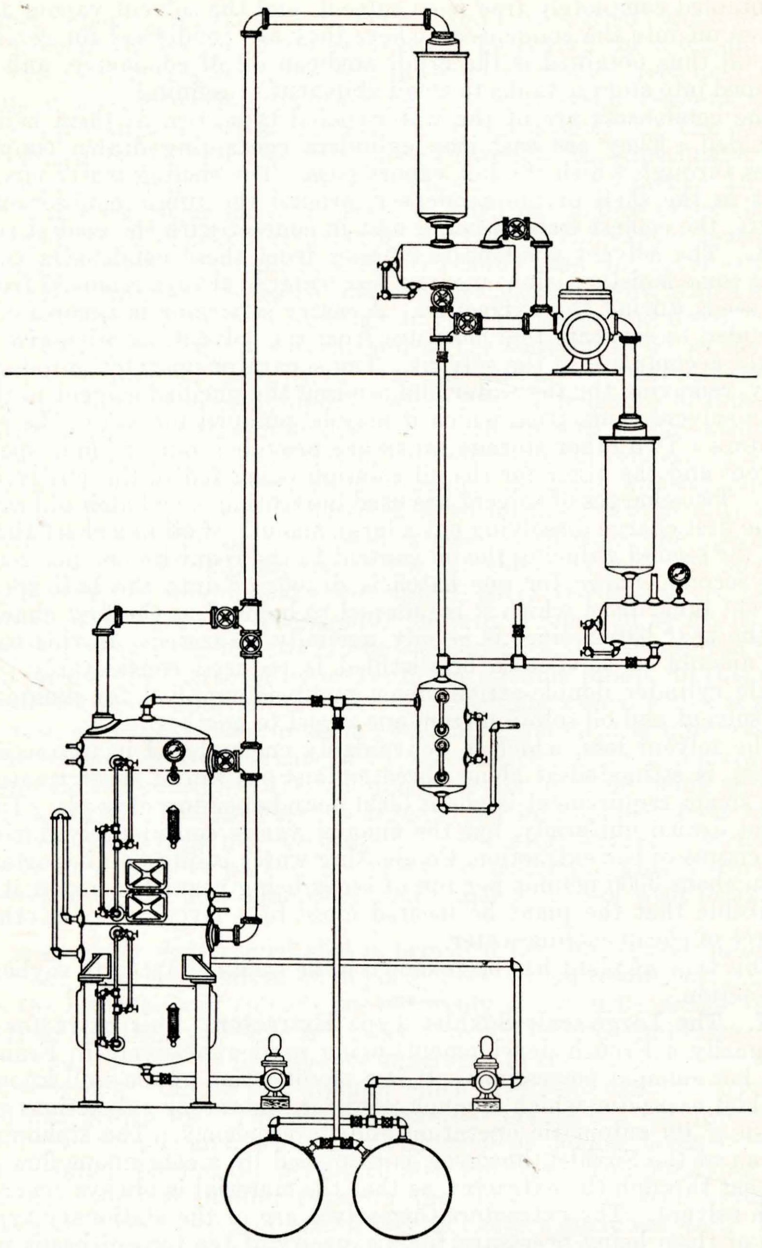

Fig. 4. Soxhlet Type Solvent Extraction Plant.

tom of which a still is built, separated from the extraction vessel proper by a closed horizontal partition.

For the preparation of the seed for extraction, the manufacturers recommend the use of a single pair or rolls operating at different speeds. This tears open the seed, and exposes the oil cells with a minimum of pulverized material. A minimum amount of handling of the crushed seed is advisable, so as to avoid further reduction. It is best to make use of gravity feeds into the extractors, but, where this is not feasible, bucket conveyors are likely to increase the amount of fines, while cloth or rubber-belt conveyors are attacked by the oil. The extractors are charged from hoppers, the material entering the extractor through the upper door and resting on a filter screen near the bottom.

The extraction is commenced by introducing the solvent through a valve at the bottom of the extraction vessel and allowing it to rise slowly through the charge. In this way, the air is forced out ahead of the solvent, and channeling, air pocket formation, and uneven wetting are avoided. The oil bearing solvent overflows at the top through a filter screen built around the inside of the charging dome; going to the still in the bottom of the extractor. Heat is applied through a steam coil in the bottom of the still, and the solvent is vaporized, the vapors passing to the condenser. The hot liquid solvent, obtained by condensation, is returned to the extractor, so that the extraction is carried out at a temperature only slightly below the boiling point of the solvent, and is thereby accelerated. The process is continued for several hours, until the oil content of the residual meal is reduced to about one per cent. At this point, solvent vapor is admitted to the extractor directly from the still, displacing the hot solvent, which is drained into the still. The vapors in turn are displaced by the introduction of live steam; thus producing a meal quite free from solvent taste and odor. Several installations of this type are in use for the preparation of human foods. The last traces of solvent are removed from the oil in the still by steam distillation, steam being admitted through a perforated pipe.

The meal is discharged from the extractor by hand through a door just above the still. It is stated that the labor thus involved is not an extra item of expense, since the time required for discharging the extractor is the same whether the operation is performed by rotating the extractor, by means of an agitator, or by simply raking the material out by hand. In each case the time is about ten to fifteen minutes, which is not excessive. Since the meal has been subjected to direct steam, it is necessary to adjust the final moisture content so that it will not be high enough to cause spoilage. This is done by passing the meal through a steam jacketed trough by a screw conveyor, the excess moisture evaporating during the passage.

A scrubbing tower is provided for the recovery of solvent vapors which otherwise would pass out with the air expelled from the ex-

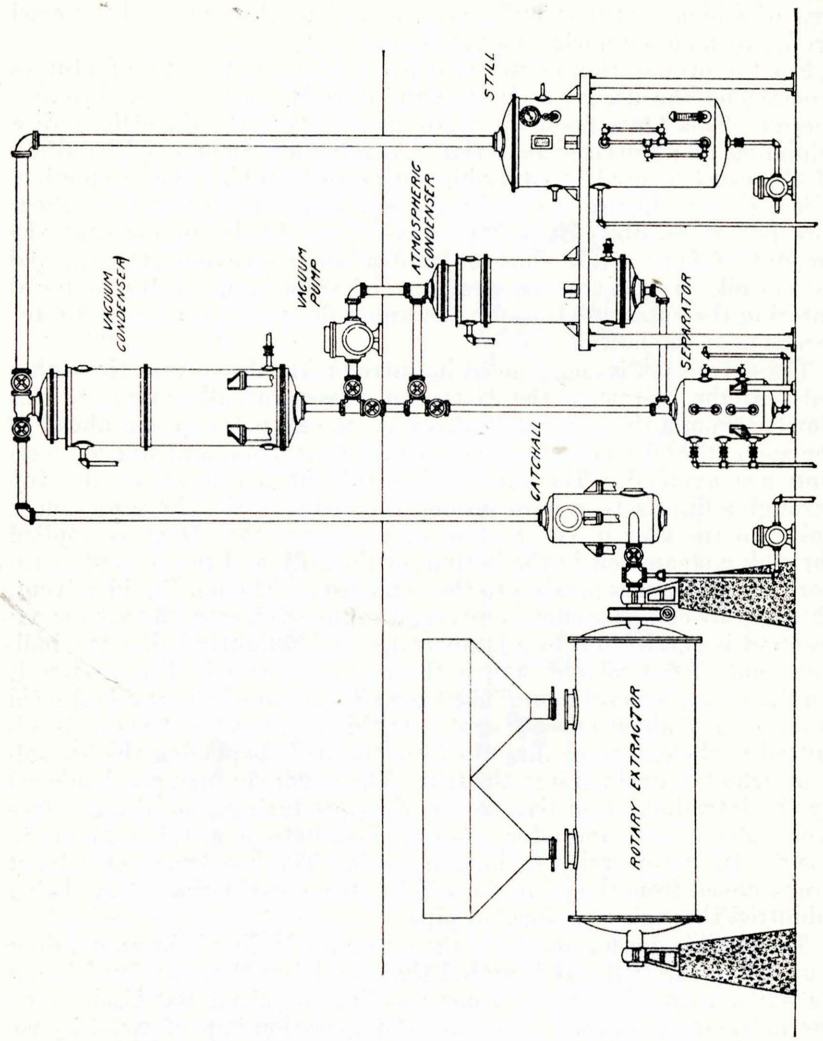

Fig. 5. Rotary Type Solvent Extraction Plant.

tractor and condensers; thus any uncondensed vapors escaping from the condensers are absorbed in the oil flowing through the scrubbing tower, resulting in a lower solvent loss. The unavoidable loss in a ten ton plant is about ten to fifteen gallons per day.

III. The Rotary Extractor. The rotary extraction system differs from the stationary principally in the means employed for the agitation of the extractor charge. The extractor itself is a large horizontal steam jacketed steel drum, mounted on trunnions, provided with one or more charging doors. Live steam inlets to the interior of

the extractor are provided if steaming is resorted to for freeing the meal from the solvent. Hot air may be used for drying the meal. The drum is constructed so as to operate under vacuum for removing the residual solvent. Steam is introduced into the outer jacket, and the traces of solvent are evaporated at reduced pressure. To enable easy drainage, a filter screen is provided, usually extending the length of the extractor, which prevents the removal of meal particles with the oil solution. The dimensions of the drum in a ten ton plant are from five to six feet in diameter and fourteen to eighteen feet in length; three charges of about three tons each are made every twenty-four hours. The drum is rotated at the rate of about one revolution per minute, thus tumbling the charge about and insuring good contact of the ground beans with the solvent. A twenty or twenty-five horsepower motor is used for this purpose.

In the operation of the extractor, the manhole covers are removed, and a charge of flattened beans is allowed to flow in from hoppers above the extractor. The covers are replaced, and the solvent is pumped in. This first solvent wash is made with the partially spent solvent remaining from a previous run. The extractor is then rotated for about half an hour, is then stopped with the filter screen on the bottom and the solution, containing most of the oil in the beans, is drawn off by a pump, forced through a filter press to remove fine particles of meal, and stored in a tank to await distillation. A second wash is now made in the same way, but for a longer time, as the remaining oil is removed with more difficulty. The solution thus obtained is stored in a separate tank to be used as the first wash in the next run. If steaming is to be used, the extractor is connected to the condensers, and live steam turned into the meal. This is done under reduced pressure, none of the steam being allowed to condense in the extractor, but part of its sensible heat is used to drive off the residual solvent. The vapors drawn off pass through a dust collector to remove fine particles of meal, and are then condensed in the vacuum condenser. In some types, no steam is used, the pressure reduction alone being relied upon to effect the complete removal of solvent. One system uses a current of heated air to dry out the meal, the solvent vapors being recovered from the air by a special condenser.

The solvent nearly saturated with oil is pumped from the extractor into the still, where the oil is recovered by distilling off the solvent under vacuum to enable a low temperature to be used, thus avoiding burning of the oil. The still is a cylindrical tank equipped with closed steam coils of the proper size to cause a rapid evaporation of the solvent. In some types of extraction plants, a second or finishing still is provided, into which the liquid from the first still is pumped after most of the solvent has been removed. The finishing still is provided with heating coils and with live steam inlets, by the

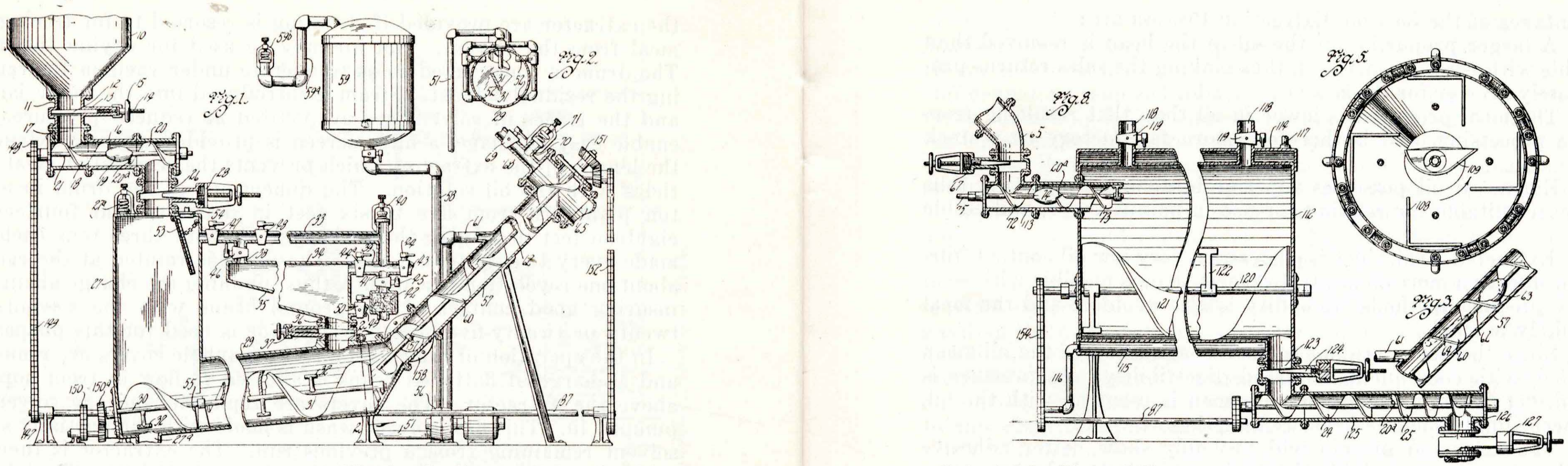

Fig. 6. Continuous Extraction Plant as Patented by Flumerfelt.

use of which the removal of the last traces of solvent from the oil is assured. The condensers used are of the tubular type with steel shells and copper tubes; the solvent vapors passing through the tubes, with the cooling water circulating around them, or vice versa. Usually, two condensers of similar construction are supplied, a vacuum condenser between the vacuum pump and the still or extractor, and an atmospheric condenser following the pump, with one end open to the atmosphere. The solvent flowing from the second condenser passes through a water separator, where any moisture present is automatically removed, and then is pumped to the solvent storage tank for further use. The oil left in the still may be pumped through a filter press to clarify it, with the previous addition of a small amount of Fullers earth or similar filter aid, after which it is pumped into the oil storage tank to await shipment.

IV. Continuous Extractors. A continuous extraction plant having a capacity of 1000 to 1200 tons of soybeans a day is operated in Germany by the Hansa Company (30). In the Hansa extractors a series of wire baskets are fastened to an endless chain in a manner similar to a bucket elevator operating in vertical position. The baskets are freely pivoted so that they are open side up until they have made almost a complete revolution and are ready to dump. The beans are fed continuously into the baskets as they pass the upper position and they are dumped out after the baskets have gone down and back almost to the filling point. Fresh solvent is sprayed onto the partially exhausted beans as they come into a position about half way up

toward the dumping point. This solvent passes to the bottom of the extractor through a series of the baskets. The solvent, containing considerable oil, is pumped from the bottom and sprayed onto the fresh beans entering the extractor.

It is claimed that this process can be operated with a steam consumption not greater than 1200 pounds per ton of beans and with electric power not over 30 kilowatt hours per ton of beans. Only 6 tons of solvent is used for each 100 ton per day capacity.

A continuous process said to be suitable for a small scale plant is being experimented with by the Ford Motor Company. In this process the flaked beans are fed into the bottom of a pipe set at a 10 degree angle and fitted with a screw conveyor.

The flaked beans are moved through the pipe against the solvent, which flows in at about halfway between the upper and lower end. The upper end of the pipe forms a steaming chamber where the solvent is vaporized off. A similar process has been patented by Flumerfelt (13) the apparatus for which is shown in Fig. 6. In this process the flaked beans are fed into a tank through a screw conveyor arranged so that the bean meal acts as a stopper, preventing solvent vapor escaping from the tank. The beans are removed from the tank by a screw conveyor down through which the fresh solvent flows to the tank. The solvent oil solution is drawn off from the top of the tank from where it goes to the solvent recovery apparatus. The extracted bean meal goes from the conveyor to a drying chamber in which the solvent is evaporated off.

Advantages of the Solvent Extraction Process are:

(A) A larger proportion of the oil in the bean is removed than is possible with pressure methods, thus making the sales returns proportionately greater for the same overhead.

(B) The meal produced is lower in oil than that resulting from pressure processing, and is therefore more satisfactory as a stock food.

(C) Extracted oil possesses superior bleaching properties, thus being more suitable for refining for use in paints, soaps, and edible oils.

(D) Extracted meal, since it possesses a very low oil content, furnishes protein in a more concentrated form than is possible with meal made by pressure methods; rancidity is also avoided, and the meal is less likely to spoil.

(E) Since the beans are not cooked, coagulation of the albumen is avoided, with consequent increased digestibility. As pressure is not used, very little mucilaginous albumen is removed with the oil, which accordingly shows a lower refining loss.

(F) The extracted protein will probably show better adhesive properties for a size material in the lumber substitute industry.

(G) By the extraction method less oil is left in the meal to be sold at the meal price of two cents per pound instead of the oil price, 9.25 cents per pound. This difference on a twenty bushel per acre yield of beans containing eighteen per cent oil amounts to $2.27 per acre on a ten ton per day plant or $11,350 per year. The data are given in detail in Table 17.

V. Extraction Solvents. A large part of the early failure to develop extraction process satisfactorily, is traceable to the unsuitability of the solvent used. The solvent being incompletely removed from the oil and meal, imparted a very noticeable taste and odor to these products, which seriously affected their market value and built up prejudice against the solvent extraction system. At present, however, solvents are used which are easily and completely removable, and the oil and oilmeal is entirely free from solvent taste and odor.

The first requirement for a commercial solvent is that it be a specific solvent for the oil in question, that is, it must dissolve the oil only, leaving behind the mucilage, coloring matter, and other substances which are undesirable in the oil. It should preferably be noninflammable and non-explosive, since this feature will result in considerably lower insurance rates and less danger to the plant. With modern apparatus and methods for solvent recovery, however, the fire hazard is not a prohibitive feature. In order to facilitate the separation of the solvent from the oil and meal, it is necessary that the solvent be homogeneous in composition, and distill completely within a fairly narrow range of temperature. A light fraction in the solvent is difficult to condense, and its escape into the atmosphere not only increases the fire hazard but also means a considerable financial loss, since most practical solvents are quite expensive. Heavy fractions are very tenaciously retained by the oil and meal, and cannot be removed by distillation or steaming. The use of solvents containing heavy ends was a principal cause of failure in the earlier attempts to make solvent extraction practical on a commercial scale. It is desirable to have the entire solvent distill at a temperature below the boiling point of water, as otherwise difficulty will be encountered in deodorizing the oil and meal. Finally, the solvent must be easily and cheaply obtainable, this often being the determining factor in the choice of a solvent.

In classifying solvents according to the fire hazards, three classes may be distinguished. Inflammable solvents are petroleum ether, gasoline (both the ordinary varieties and the specially refined solvent gasolines), ether, benzol, carbon disulfide, and acetone. Ethylene dichloride is an example of semi-inflammable solvents, as it ignites only under conditions which are not likely to be met with in practice. In this class there are also numerous mixtures of inflammable solvents with non-inflammable ones, the latter being added in such proportion as to make the mixture not readily inflammable. The non-inflammable solvents are principally those containing chlorine, such as trichloroethylene, carbon tetrachloride, and trichloroethane.

A special cut of gasoline is the most commonly used inflammable solvent. Ordinary motor fuels are distinctly unsuitable for this purpose, since the heavy ends they contain are separable from the oil and meal with great difficulty. An experimental extraction at the Iowa State College using ordinary motor gasoline demonstrated this fact quite conclusively. Distillation began at about 110° C., and continued up to about 180° C.; at this point, the residue in the still was less than fifty per cent oil, the remainder being heavy ends, which could not be distilled out and which commenced to crack at about 180° C. At this high temperature, the soybean oil had commenced to decompose, and further progress in the distillation was manifestly impractical. A special light cut of gasoline, boiling at much lower temperatures, is far superior to the motor fuel variety. Extremely light petroleum fractions are undesirable, owing to the greater fire risk and solvent losses, as well as higher cost. Gasoline, though inflammable, is obtainable for about twenty-five cents a gallon in large quantities, and because of its low cost, its inertness toward iron apparatus, ease of distillation, and excellent solvent properties, it is the most nearly ideal solvent now available. The most desirable boiling range will lie between 125° F. and 200° F.

Laboratory solvents such as ether, carbon disulfide, and acetone are not practical on a large scale, because of their high cost, excessive inflammability, corroding qualities, or scarcity. Benzol or benzene, boiling at 176° F., is quite well suited for extraction, and is not expensive. But it has a tendency to dissolve colored substances and hence produce a dark oil. Being a pure compound, it presents no difficulties due to the presence of heavy ends, and consequently is readily removed from the oil and meal, easily distilled, and easily condensed. It is quite toxic and care should be exercised by workmen in its use.

Ethylene dichloride is now being manufactured on a large scale in this country, and is available in tank car lots at six cents a pound. It boils at 182° F., and has a specific gravity of 1.26. A concentration in air of six per cent is required before explosions can occur, while with gasoline the lower limit is 1.5 per cent. Since even very small amounts of the vapor are easily detected by the odor, the fire hazard is small. The explosion is not violent, and requires an open flame to start it. The liquid is not very inflammable, a fire being easily extinguished by a slight draft, or, in contrast to gasoline, by water, since the dichloroethylene is heavier than water. It has excellent solvent properties and considerable penetrating power, together with lesser tendencies to hydrolyze to form hydrochloric acid and to dissolve colored substances than other chlorine compounds, such as dichlorothylene and dichloroethane.

Numerous solvent mixtures have been proposed, chiefly with the object of avoiding inflammability and high cost while retaining the desirable qualities of some expensive, inflammable solvent. In this way, benzol or petroleum fractions may be mixed with trichloroethylene, carbon tetrachloride, or some other non-inflammable solvent, the resulting product being semi-inflammable, medium priced, and a good solvent for the oil, but yet avoiding the tendency of the chlorine compounds to hydrolyze and to dissolve unwanted substances.

The principal non-inflammable solvents which have been used or proposed have been chlorine-containing compounds, the inflammability being reduced by the presence of the chlorine. Unfortunately, such solvents have more or less marked tendencies to hydrolyze, reacting with the moisture in the material being processed, to form hydrochloric acid, which corrodes the equipment, or else poisonous compounds which are dangerous to the plant employees and to the consumers of the products. Carbon tetrachloride has been definitely rejected on this account, as the corrosive effect on the iron vessels is too great.

Trichloroethylene, which boils at 190.4° F. and has a specific gravity of 1.46, has been used in several European extraction plants for several years without noticeable ill effects from corrosion. Laboratory tests have shown that over thirty years would be required before an extractor would be worn out from this cause, so that it appears that corrosion is not a prohibiting factor in the use of trichloroethylene as a solvent. The cost is about nine to ten cents a pound in large quantities, and this, together with its high specific gravity does not compare very favorably with that of gasoline. This

solvent is absolutely non-inflammable, and presents no fire or explosion risks. It is, however, quite strongly narcotic, and so any escaping vapors will have a toxic effect on the workmen. A case of cattle poisoning from meal extracted with trichloroethylene has been reported in Europe, but the evidence is not conclusive, and the toxicity may have been caused by incomplete removal of the solvent rather than by irremovable residual poisons.

Plant Design

A plant having a capacity of ten tons of beans in a twenty-four hour day, or 100,000 bushels a year, has been selected because it is believed this size is best suited for Iowa conditions. Smaller capacity plants, while they might be desirable from the standpoint of available bean supply in a particular locality, require an initial investment almost as great as the ten ton size, and make no provision for the future expansion. Larger capacities naturally require proportionately larger investments, thus multiplying the difficulties of financing. A ten-ton plant, drawing its bean supply from a territory only a few miles quare, becomes a community affair, which may easily be financed by a few investors, and the meal produced can be cheaply returned to the farm for stock food. In addition, it is well to begin an infant industry on a small scale in order that its possibilities may be well analyzed before extensive developments are undertaken. An additional reason for the use of ten-ton plants is that this size is a very common one among the manufacturers of all types of oil equipment, requiring only one or two units of extractors, presses, or expellers.

Cost data for the various types of installations have been obtained directly from several manufacturers. The cost of a suitable building for housing the equipment has been determined with more difficulty, being quite dependent on local conditions. The prevailing tendency will likely be to make use of abandoned factory buildings wherever these are available. This will, of course, make necessary a separate design of each individual installation, which cannot be predicted beforehand. For purposes of cost calculation, the cost of a building has been estimated at about $7000, including whatever equipment is necessary for receiving, and conveying the beans and oilmeal. This amount will usually be sufficient to cover the cost of a brick building of ample dimensions for housing the machinery and providing some storage space. Storage elevators for a plant of this size do not appear to be a necessity, and represent a considerable investment if storage room for the year's supply of beans, or a large part of it, be supplied. It is desirable to provide space for several weeks' supply, the best arrangement being to have each grower retain his beans until needed by the mill. In this way, the necessity for large elevators is

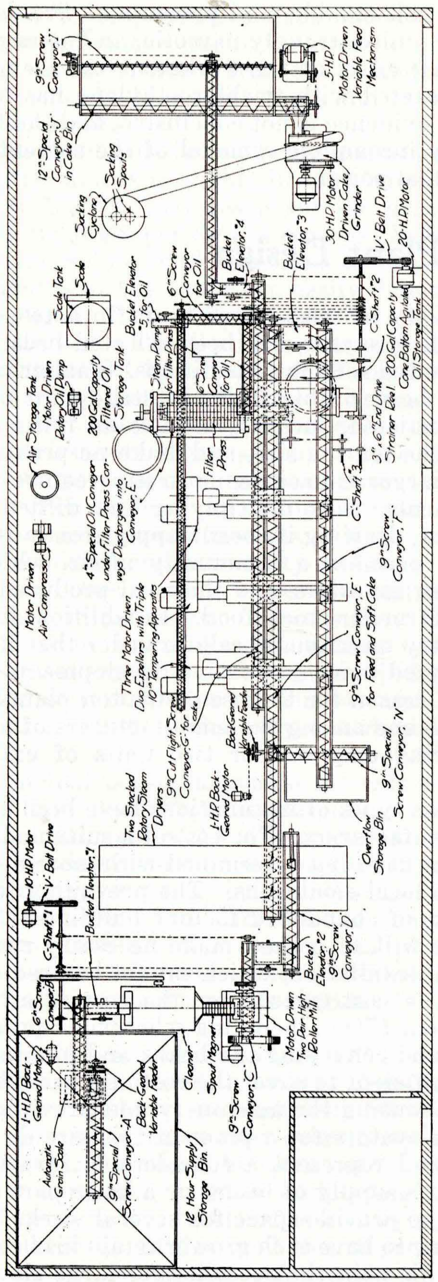

Fig. 7. Layout of a Three-Expeller Soybean Oil Plant.

Courtesy The V. D. Anderson Co.

This plant has a capacity of 1200 bushels (36 tons) of soybeans per 24 hours producing an oil cake with about 5 percent oil at 10 percent moisture. The labor cost with this size plant is practically the same as a one-expeller plant thus giving a lower production cost.

obviated, while each farmer will need but a small space for his own crop. An additional advantage is that the drying out of the beans after harvesting does not occur in large bins, thus minimizing spoilage due to heating. Under this plan the beans could be contracted for in the fall for delivery at specified times during the year.

Large manufacturers feel it is better to hold a large supply in storage. If storage is required the cost of a suitable elevator will be approximately $12,500 and will hold more than one-half year's supply.

The boilers specified in the cost calculations are of a very convenient portable type, shipped ready for use; the expense of a costly brickwork setting is thus avoided, and the boiler is readily moved about at low cost. Included in the price of the building is the cost of a steel stack for the boiler.

The allowance of $7000 for a building is intended to cover the cost of a brick structure about thirty feet wide, forty feet long, and thirty feet high, which is about the average requirement. Building dimensions for several designs are:

Type D Rotary Extractor 33 ft. x 42 ft. x 32 ft. (2 stories)
Type G Rotary Extractor 33 ft. x 39 ft. x 24 ft. (1 story)
Type B Rotary Extractor 34 ft. x 59 ft. x 32 ft. (2 stories)
Type W Rotary Extractor 40 ft. x 60 ft. x 30 ft. (1 story)
Scott Stationary Type 18 ft. x 45 ft. x 27 ft. (2 stories)
Hydraulic Press Plant 35 ft. x 34 ft. x 20 ft. (1 story)

The second stories of the Scott and Type B buildings are simply charging floors, and half of the Type B building is of one story only, so that this plant may be housed in a two-story building of smaller area. The Type W plant, since it uses two extractors and considerably more accessory apparatus than the other types, may require a somewhat larger building, even though two stories be used instead of the one. The Expeller plant requires little room, consisting only of the dryers, crushers, and expeller units, together with a very small boiler. It is advisable, especially with extraction plants, to have the boiler and motors so placed as to minimize the danger of explosions. This is easily done by setting the boiler in a small lean-to built against one side of the building, and placing the driving motor and crusher in a separate room or on the second floor. The storage tanks for the solvent should be located in an underground cellar at some distance from the plant, to reduce the fire hazard. The oil storage tank is preferably placed at such a level that pumping is unnecessary when the oil is delivered into tank cars for shipment, thus saving much time and expense.

A weighing platform and wagon dump should be provided outside the building, for weighing the beans as the farmers bring them in, although for small plants scale privileges can often be rented. A chain-and-bucket type elevator carries the beans from the dump to the second floor, where sufficient storage space is provided to care for several days' supply. On this floor the crusher and driving motor are located, with a speed reducer for connecting the motor and extractor, if the latter is rotary or uses agitators. The crushing is then done when the motor is not in use for agitation purposes. A screw conveyor brings the beans from the storage bins to the crusher, which is so located as to discharge directly into the hoppers above the extractors, cookers, or expellers, to avoid extra handling and production of fines, and to make use of gravity conveyance. The amount of power used by the conveying system is, however, quite small in any case, and is not a determining factor in the design of the plant. The amount of conveying equipment will naturally depend on the layout of the mill, and hence cannot be specified definitely until the size and shape of the building to be used is known. Since this will vary from plant to plant, no attempt has been made to calculate its cost. It will not usually exceed $200 in a ten-ton plant. A railway siding is provided at an estimated cost of $3600. A well for cooling water is estimated at $600 complete with pumping equipment.

Facilities for the bagging and shipping of the oilmeal must be provided. If the meal is returned to the bean growers loose, a loading hopper over a wagon road should be supplied, with a conveyor to bring the meal from the extractor, expeller, or press. Otherwise, the meal must be weighed out into bags, either by hand or automatically, and then placed in cars for shipment. Storage space will not be necessary unless the market is poor, since a carload of meal is produced in about two days, and a car can be loaded within the demurrage limit. For this purpose, it is very desirable that the plant be located on a railway siding. This will also be of value in the shipping of oil and the receiving of solvent. The oil may be shipped in tank cars or in drums.

Production Costs

Operating Costs

The principal items of expense in the operation of an extraction plant are steam, solvent loss, cooling water, power, repairs, and labor. Each of these will differ among the various types of plants, owing to variations in the method of processing and in the construction of the apparatus, but in general the operating costs of the different types will be approximately equal. Hydraulic press and expeller plants will have no solvent loss, and the water requirement is limited to that small amount necessary for tempering and steam raising.

The steam requirement for the different types of extraction plants varies with the method of processing, being usually between 30,000 and 45,000 pounds daily. Where steaming is resorted to for freeing the meal from the last traces of solvent, the steam consumption will be increased. Most of the steam used, however, is for the separation of solvent and oil by distillation, while some steam is used in the extractor jacket for heating the charge during the extraction process. A boiler capacity of fifty to seventy-five horsepower is sufficient for a ten-ton-per-day plant. A 100 horsepower boiler would take care of temporary overload and of future expansion. The steam consumption in an expeller plant is very small, since steam is used only for tempering the ground beans; a five horsepower boiler being ample for a two-expeller installation. A hydraulic press plant requires a twenty horsepower boiler, since steam is used for the cooking operation, which requires longer heating than tempering.

Solvent losses in an extraction plant, due to incomplete condensation of the vapors from the stills, leakage, or other causes, usually varies from twenty to fifty gallons per day, depending mainly on the condensation efficiency. In the Soxhlet type, a scrubbing system is used to remove most of the solvent vapors escaping from the condensers, so that the losses in this case amount to only fifteen gallons per day. The Type W rotary extractor, using an elaborate recuperation system, has a very low solvent loss. With solvent costing twenty-five cents a gallon, the solvent loss represents a considerable item in the operating expense.

Large quantities of water are required for cooling and condensing the solvent vapors after distillation, making imperative a constant and reliable source of water. From 25,000 to 50,000 gallons per day is the usual requirement, with 30,000 gallons being about average for all types of extraction plants. An additional quantity of water is necessary for steam raising purposes, averaging about 4,000 gallons daily. In this connection, the cost of treating the water previous to its use in the boiler is to be considered. If the plant is located near a lake or river, cooling water may easily be pumped at low cost, ten cents a thousand gallons or less—as water for this purpose need not be especially clean or pure. It will usually be considerably cheaper to drill a deep well than to purchase water from city mains. If the use of city water becomes necessary, it might be desirable to install a cooling system which would enable the continued recirculation of the cooling water, and thus limit the supply necessary. Well water is of a more uniform temperature and for that reason gives better operating conditions throughout the year.

A hydraulic press plant requires about thirty horsepower for its operation usually supplied by an electric motor. An expeller plant uses one twenty-five horsepower motor on the expellers, and a twenty horsepower motor to operate the crusher and conveyors. The power requirements for rotary extractors vary, from fifteen to thirty horsepower being necessary, depending on the type. If the extractor is rotated during the entire extraction period, power requirements will naturally be greater than if rotation continues for only a few minutes. The time of rotation is set by the operator, and should be adjusted so as to give maximum extraction efficiency with minimum power expenditure. It is desirable to drive the extractor and the crusher from the same motor, thus saving the cost of an additional motor; the crushing being done between periods of rotation of the extractor, which are usually several hours apart, and the conveying of the crushed seed is done at this time also. The agitators on the Scott stationary extractor are used only for short periods, while in the Soxhlet type, the motor is used only to operate the crusher and conveyors. The power necessary for conveyor operation is very small, and hence is of slight importance in the calculation of motor sizes.

It is obvious that to keep overhead, interest and depreciation from absorbing the profits the plants should be operated at full capacity and for as many days in the year as possible.

Calculation of Costs

The milling costs have been variously obtained, the accuracy of some of the items may be questioned, but the deviations from the given total will not be great. Solvent losses will of necessity depend upon the method of processing and the mechanical construction of the machinery. Where scrubbing towers or recuperators are provided the losses will be lessened. The cost of solvent has been set at twenty-five cents a gallon. The cost of coal used for steam raising has been taken as $4.50 a ton, with an evaporation of six pounds of water per pound of coal fired. Water has been estimated at fifty cents a 1000 cubic feet. Labor requirements will depend somewhat upon local conditions, but two men per shift should be able to attend to all operations in the plant, including the bagging of meal, as much of the work requires attention only at intervals. For the expeller plant, thirty-six man-hours per twenty-four hours have been allowed, since the expelling process is more of an automatic nature than pressing or extraction, therefore requiring less attention, and no solvent to distill. Ample allowance has been made for power used for all purposes—crushing, pumping, conveying of solids, and operation of the extractor, press, or expeller. Crushing costs are not easily estimated without actual data, since the process is one of flattening and not of subdivision. Water pumping cost will depend on local conditions, such as average water temperature (since the volume of cooling water depends on its temperature), pumping distance, etc. Conveying of materials around the plant will not require a large amount of power, and the cost will depend on the plant layout, which should be made with this point in mind. However, the power requirements used as a basis for calculations are sufficiently large to care for any item which might unexpectedly arise.

Depreciation costs have been figured by the sinking fund method; each year a constant sum is set aside, bearing interest at six per cent, so that when the end of the useful life of the apparatus is reached, the fund accumulated will be just sufficient to pay for its initial cost. A life of ten years has been assumed for equipment, and 20 years for the building, siding, well, and pumping equipment. A zero scrap value at the end of these periods has been assumed, with the intention of allowing in this way for any repair costs which may be incurred. The latter are generally not predictable, nor is the life of the equipment. In the case of expellers, a repair cost of about $100 a year per machine may be expected, mainly the cost of replacing worn parts.

TABLE 17. COMPARATIVE FINANCIAL RETURNS BY VARIOUS METHODS

	Expeller	Hydraulic press	Extraction
No. of bushels to acre			20
Lbs. per bu.			60
Lbs. per acre			1,200
Per cent oil			18
Manufacturing loss			5%
Oil left in cake	5%	6%	1%
Yield cake per acre	991.8 lb.	1,003.2 lb.	946.2 lb.
Yield oil per acre	148.2 lb.	136.8 lb.	193.8 lb.
Value of cake at $40 ton	$ 19.84	$ 20.06	$ 18.92
Value of oil at 9.25c per lb.	$ 13.15	12.65	17.93
Total value	32.99	32.71	36.85
Cost of processing per bu.*	0.20	0.21	0.26
Net return to pay for each acre after allowing 12% profit	28.99	28.51	31.65
Gross return (no profit allowed)	29.00	29.21	32.19
Difference in net return above that of Expeller Method	.00	.44	2.66
No. of bu. per year (300 days of operation) used by 10-ton (333.3 bu.) plant			100,000
No. of acres to supply plant (20 bu. to acre)			5,000
Difference in return of extraction above expeller method per year			$ 12,400

*See detailed statements in Tables 25, 26 and 27.

Insurance and taxes have been set at 2.5 per cent of the investment. An extraction plant housed in a well built fireproof building, with ample means of fire prevention and control, should not demand an insurance rate exceeding this amount, although if a considerable fire hazard exists, the rate will increase accordingly.

The management of a plant of this size does not require a high degree of technical or business ability. The amount of office work will be small and not difficult. The sales of oil will be done through brokers on commission basis, the usual charge being one per cent. However, there are possibilities of marketing the oil from a small plant at several times the market price by skilled sales managers. Small users usually pay well above the market. The oil meal will be sold in the same manner or it may be sold direct from the plant to the farmers. The management, office, and sales expense has been placed at $3000. An allowance of one per cent brokerage charge has been made on the oil and oilmeal.

The investor's profit has been set at twelve per cent of the total investment, merely to get a value for beans. In a small plant, it should be possible for an owner or principal stockholder to supervise the plant in a general way, and attend to the office work. The

TABLE 18. ROTARY EXTRACTION PLANTS—COST CALCULATIONS—I.

Operating Expense Items	Type D	Type G	Type S
Lb. steam per day	43,200	44,500	44,500
Cooling water, gal	30,000	47,500	47,500
Total water, gal	35,200	52,850	52,850
Power, KWH	360	360	360
Solvent loss, gal	48	36	36
Milling Cost per Day			
Labor	$24.00	$24.00	$24.00
Coal	13.50	13.50	13.50
Solvent loss	12.00	9.00	9.00
Power, electric	10.80	10.80	10.80
Water, total	2.35	3.50	3.50
Total cost	62.65	60.80	60.80
Equipment cost	$ 17,890	$ 29,850	$ 23,850
Siding and well	4,200	4,200	4,200
Building cost	7,000	7,000	7,000
Total investment	$ 29,090	$ 41,050	$ 35,050
Annual Expenses*			
Management and office	$ 3,000	$ 3,000	$ 3,000
Milling costs	18,795	18,240	18,240
Depreciation, building	190	190	190
Depreciation, siding and well	114	114	114
Depreciation, equipment	1,357	2,265	1,820
Insurance and taxes**	727	1,026	876
Profit to investor	3,490	5,310	4,211
Total annual cost	$ 27,673	$ 30,145	$ 28,451
Sales Returns			
On oil at 9.25c lb	$ 89,700	$ 89,700	$ 89,700
On oilmeal at $40 per ton	94,620	94,620	94,620
Total gross returns	$184,320	$184,320	$184,320
Brokerage 1%	1,843	1,843	1,843
Net returns	182,477	182,477	182,477
Returns—Annual costs	154,804	152,332	154,026
Maximum price of beans (bu.)	$ 1.55	$ 1.52	$ 1.54

*Operating 300 days per year.
—By sinking fund method; 6% interest; zero scrap value; life of building 20 years; equipment 10 years; siding and well 20 years.
**Estimated at 2.5% of investment.
NOTE: Type letters refer to detailed description given in table 24 and following.

calculations are quite close and any considerable variation in any one of several factors—such as oil and moisture content of the beans, available supply, and prices of the beans, oil and meal are sufficient to absorb all the profits and even more, since the profit lies between $2000 and $6000 annually, while the volume of business approaches $200,000. Any other interest rate can be readily substituted in the calculations to arrive at a value for the beans.

Sales returns on the crude oil are based on the prevailing price of 9.25 cents a pound in tank cars, on the Pacific Coast. Iowa oils produced close to the industrial centers of the country should command a slightly higher price in view of the lower freight costs and the superior quality of the oil as compared to the imported product. The oil meal has been figured at $40 a ton or two cents a pound, which is very conservative; linseed meal sells at $46, and cottonseed meal at $43. Soybean meal is at least equal to these in feeding value, and does not have the poison risk of cottonseed meal nor the laxative effects of linseed oilmeal. Very little soybean meal is available on the

TABLE 19. ROTARY AND SOXHLET EXTRACTION PLANTS—COST CALCULATIONS—II.

Operating Expense Items	Type B	Type W	Soxhlet Type
Lb. steam per day	30,000	19,200	42,000
Cooling water, gal	28,500	28,000	60,000
Total water, gal	32,100	30,300	65,000
Power, KWH	360	320	270
Solvent loss, gal	20	—	15
Milling Costs per Day			
Labor	$ 24.00	$ 24.00	$ 24.00
Coal	9.00	6.00	13.50
Solvent loss	5.00	—	3.75
Power, electric	10.80	9.60	8.10
Water, total	2.15	2.00	4.35
Total costs	$ 50.95	$ 41.60	$ 53.70
Equipment cost	$ 40,100	$ 38,797	$ 17,450
Siding and well	4,200	4,200	4,200
Building cost	7,000	7,000	7,000
Total investment	$ 51,300	$ 49,997	$ 28,650
Annual Expenses*			
Management and office	$ 3,000	$ 3,000	$ 3,000
Milling expenses	15,285	12,480	16,110
Depreciation, building†	190	190	190
Depreciation, siding and well	114	114	114
Depreciation, equipment	3,050	2,945	1,325
Insurance and taxes**	1,282	1,250	716
Profit to investor	6,156	6,000	3,438
Total annual cost	$ 29,077	$ 25,979	$ 24,893
Sales returns			
On oil at 9.25c per lb.	$ 89,700	$ 89,700	$ 89,700
Oilmeal at $40 per ton	94,620	94,620	94,620
Total gross returns	184,320	184,320	184,320
Brokerage 1%	1,843	1,843	1,843
Net returns	182,477	182,477	182,477
Returns—Annual costs	153,400	156,498	157,584
Maximum price of beans (bu.)	$ 1.53	$ 1.56	$ 1.58

*Operating 300 days per year.
†By sinking fund method; 6% interest; zero scrap value; life of building 20 years; equipment 10 years; siding and well 20 years.
**Estimated at 2.5% of investment.

market at the present time, so the selling price can only be estimated. If most of the meal is returned to the bean growers the price allowed for meal will depend to a large extent on the price paid for the beans. The final results of the cost calculations have been expressed as the maximum prices which can be paid for the beans, since this price is the controlling factor in the economics of oil mill operation.

Agricultural studies indicate that the soybean is a desirable crop for the corn belt.

The beans are not a wholly satisfactory feed, but the extracted bean or meal is an excellent protein stock food, fitting well into the scheme of feeding recommended by the experts for the corn belt.

By establishing oil mills, the oil which has the highest money value, but no fertilizer value, is sold from off the farm, while the stalks and meal with their fertility are returned eventually to the soil. This is one of the few farm commodities showing this desirable possibility.

Engineering data indicates that the oil mills would be profitable.

TABLE 20. STATIONARY EXTRACTION, HYDRAULIC PRESS AND EXPELLER PLANTS

	Stationary Extractors	Press	Expeller
Operating Expense Items			
Lb. steam per day	30,000	15,000	4,000
Cooling water, gal	30,000	—	—
Total water, gal	33,600	1,800	470
Power, KWH	320	540	800
Solvent loss, gal	30	—	—
Milling costs			
Labor	$ 24.00	$ 24.00	$ 18.00
Coal	9.00	5.60	1.50
Solvent loss	7.50	—	—
Power, electric	9.60	16.20	24.00
Water, total	2.25	.15	.05
Total cost	$ 52.35	$ 45.95	$ 43.55
Equipment cost	$ 19,470	$ 12,102	$ 11,275
Siding and well	4,200	4,200	4,200
Building cost	7,000	7,000	7,000
Total investment	30,670	23,202	22,475
Annual Expenses*			
Management and office	3,000	3,000	3,000
Milling costs	15,705	13,785	13,065
Depreciation, building†	190	190	190
Depreciation, siding and well†	114	114	114
Depreciation, equipment	1,478	919	857
Insurance and taxes‡	767	580	560
Profit to investor	3,680	2,784	2,696
Total annual costs	24,934	21,372	20,453
Sales Returns			
From oil at 9.25c lb.	$ 89,700	$ 63,270	$ 68,600
From oil meal at $40 a ton	94,620	99,180	94,620
Total gross return	184,320	163,590	167,780
Brokerage 1%	1,843	1,635	1,678
Net returns	182,477	161,964	166,102
Returns—annual costs	157,543	140,592	145,649
Maximum price of beans (bu.)	$ 1.57	$ 1.40	$ 1.46

*Operating 300 days per year.
†By sinking fund method; 6% interest; zero scrap value. Life of building 20 years, equipment 10 years, siding and well 20 years.
‡Estimated at 2.5% of investment.

TABLE 21. TYPE D ROTARY EXTRACTOR PLANT.

Equipment Cost	
1 rotary extractor, with all auxiliaries.	
1 solvent tank, 5 ft. diam. by 15 ft. long.	
1 condenser complete.	
1 still for recovering oil.	
1 water separator.	
1 air heater.	
1 exhauster.	
1 condenser for removal of solvent from air used.	
1 set of pipe connections with valves.	
Cost of above apparatus, f.o.b.	$12,000
1 75-HP Boiler, portable	1,750
1 grinding mill, with gyrator sifter	1,390
Motor for grinder (20 HP) and sifter (5 HP)	350
2 10,000 gal. storage tanks for solvent and oil	1,000
Freight charges	400
Erection cost	1,000
Solvent loss	2% or 48 gal. per day
Power requirements	25 HP
Cooling water	30,000 gal. per day
Steam requirements	1,800 lb. per hour (estimated)

TABLE 22. TYPE G ROTARY EXTRACTION PLANT

Equipment Costs	
1 rotary extractor, with hoppers for holding beans and meal.	
1 dust collector.	
2 condensers, atmospheric and vacuum.	
1 water separator.	
1 vacuum pump.	
1 solvent pump.	
1 oil recovery still.	
Cost of above apparatus	$24,000
1 75 HP portable boiler	1,750
1 roll crusher, 36 in. rolls, 22 in. face	1,500
1 motor for extractor and crusher, 20 HP	300
2 storage tanks for solvent and oil, 10,000 gal.	1,000
Freight charges	300
Erection cost	1,000
Solvent loss	36 gal. per day
Power requirement	20 HP
Cooling water	47,550 gal. per day
Steam requirement	1,850 lb. per hour (estimated)

TABLE 23. TYPE S ROTARY EXTRACTION PLANT

Equipment Costs	
Cost of extraction unit	$18,000
1 75 HP portable boiler	1,750
2 10,000 gal. storage tanks for oil, solvent	1,000
1 roll crusher, 36 in. rolls, 22 in. face	1,500
Motor for extractor and rolls	300
Freight charges	300
Erection cost	1,000
	$23,850

TABLE 24. TYPE B ROTARY EXTRACTION PLANT

Equipment Costs	
1 rotary extractor.	
1 solvent recovery still.	
1 oil finishing still.	
1 water separator.	
2 condensers.	
1 vapor tank for use with condensers.	
4 pumps for handling liquids.	
1 10,000 gal. solvent storage tank.	
1 6,000 gal. oil storage tank.	
1 solvent heater.	
1 extractor drive, with bearings, pulleys, clutches, and 25 HP motor.	
Cost of above apparatus	$35,500
1 75 HP portable boiler	1,750
1 roll crusher, 36 in. rolls, 22 in. face	1,500
Freight charges	350
Erection cost	1,000
	$40,100
Solvent loss	20 gal. per day
Steam consumption	30,000 lb. per day
Cooling water	28,500 gal. per day
Power required	25 HP

TABLE 25. TYPE W ROTARY EXTRACTION PLANT

Equipment Costs	
2 extractors, with offtake manifolds, intake filters, internal heating tubes, and steam valves and connection.	
2 dust filters and expansion tanks.	
2 wrought iron stills and fittings.	
4 condensers.	
2 filters, 40 in. by 40 in. by 60 in.	
1 5,000 gal. tank.	
2 2,500 gal. tanks.	
2 solvent pumps, capacity 60 gal. per min.	
2 steam pumps, capacity 70 gal. per min.	
1 vacuum pump, with jet condenser and oil injection tank.	
1 automatic water separator.	
4 wrought iron tanks, 32 in. diameter by 48 in. long.	
1 solvent recuperation plant, with tanks, oil circulating pumps, automatic still and condenser.	
Cost of above apparatus, f.o.b.	$33,225
1 50 HP portable boiler	1,372
1 30 HP electric motor for driving rolls and extractor	400
1 roll crusher, with two 36 in. diam. rolls, 22 in. face	1,500
Freight charges	800
Erection cost	1,500
Solvent loss	
Power requirements	50 KWH per day
Steam requirements	800 lb. per hour
Cooling water	28,000 gal. per day

TABLE 26. LARGE-SIZE SOXHLET

Equipment Costs	
2 combined extractors and stills.	
2 combined condensers and solvent tanks.	
1 scrubbing tower.	
1 heat exchanger.	
1 jacketed screw conveyor.	
1 crusher.	
Cost of above items	$13,000
1 75 horsepower boiler	1,750
1 20 horsepower electric motor for crusher	300
1 10,000 gal. storage tank for oil	500
1 10,000 gal. storage tank for solvent	500
Freight charges	400
Erection cost	1,000
Solvent loss	15 gal. per day
Water requirement	60,000 gal. per day
Steam requirement	1,750 lb. per hour
Power requirement	15 HP (electric)

TABLE 27. SCOTT STATIONARY EXTRACTOR

Equipment Costs	
2 stationary extractors with agitators.	
1 solvent vaporizer.	
1 solvent superheater.	
Vapor pipes for connecting extractors with vaporizer and superheater.	
2 condensers.	
1 water separator.	
1 tank for holding a charge of clean solvent.	
1 compartment tank for spent and partly spent solvent.	
1 purifying still for oil recovery.	
1 solvent pump.	
Valves and piping for connecting above apparatus.	
Cost of above items (delivered)	$13,620
1 25 HP electric motor for driving agitators	350
1 roll crusher, 36 in. diameter rolls, 22 in. face	1,500
1 75 HP portable steam boiler	1,750
2 10,000 gal. storage tanks for oil and solvent	1,000
Freight charges on last four items	250
Erection cost	1,000
Solvent loss	3 gal. per ton of beans
Cooling water needed (60°F.)	3,000 gal. per ton of beans
Steam requirement	3,000 lb. per ton of beans
Power requirement	25 HP (electric)

TABLE 28. HYDRAULIC PRESS PLANT

Equipment Costs	
1 15 box hydraulic press.	
1 single changecock for press.	
1 set of 2-high, 54 in. cookers.	
1 power cake former.	
1 stack of 5-high crushing rolls.	
1 20 in. disc huller.	
1 single crank hydraulic pump.	
1 settling trough for press.	
1 oil tank for pump.	
Hydraulic piping and fittings for connecting above.	
Cost of above apparatus	$ 7,107
Transmission equipment	1,265
1 20 HP portable boiler	879
1 30 HP motor	400
1 10,000 gal. oil storage tank	500
1 swing hammer mill	300
1 filter press	300
Freight charges	350
Erection cost	1,000
	$12,101
Power requirements	30 HP
Steam requirement	5 HP

TABLE 29. EXPELLER PLANT

1 type R.B. expeller with motor	$ 5,290
1 rotary dryer	1,980
1 20 HP motor	300
1 Disc attrition mill	550
1 5 HP vertical fire-tube boiler	255
1 10,000 gal. storage tank for oil	500
1 swing hammer mill and motor	300
1 filter press	300
Freight charges	300
Erection cost	1,500
	$11,275

TABLE 30. STORAGE ELEVATORS

3 monolithic concrete silos, each 20 ft. in diameter by 70 ft. high. Capacity, 60,000 bushels
1 screw conveyor above silos
1 screw conveyor below silos
1 elevator
1 wagon dump
1 spout to extraction plant
Estimated cost $12,500

TABLE 31. U. S. SOYBEAN OIL MILLS.

The following establishments are, or have been, processing soybeans for the production of soybean oil:

Archer-Daniels-Midland Co., Minneapolis, Minn.
The Chicago Heights Oil Co., Chicago Heights, Illinois.
The East St. Louis Cotton Oil Co., E. St. Louis, Ill.
The Eastern Cotton Oil Co., Elizabeth City, N. C.
The Elizabeth City Oil and Fertilizer Co., Elizabeth City, N. C.
Falk and Co., Carnegie, Pa.
W. F. Fancourt and Co., Philadelphia, Pa.
Ford Motor Co., Detroit, Mich.
Funk Bros. Seed Co., Bloomington, Ill.
Wm. O. Goodrich Co., Milwaukee, Wis.
W. R. Grau and Co., New York, N. Y.
The Havens Oil Co., Washington, N. J.
Kellog Spencer and Sons, Inc., Des Moines, Ia.
National Oil Products Co., Harrison, N. J.
The New Bern Cotton Oil and Fertilizer Mills, New Bern, N. C.
The Peru Products Co., Peru, Indiana.
Wm. H. Scheil, Inc., New York, N. Y.
Soybean Products Co., Cedar Rapids, Ia.
The A. E. Staley Co., Decatur, Ill.
Standard Soybean Processing Co., Centerville, Ia.
Welch, Holme and Clark, Inc., New York, N. Y.
The Winterville Cotton Oil Co., Winterville, N. C.

TABLE 32. EQUIPMENT MANUFACTURERS.

Stationary Extractors
E. B. Badger and Sons Co., Boston 14, Mass.
Ernest Scott and Co., Fall River, Mass.
Wurster and Sanger, 5201 Kenwood Av., Chicago, Ill.

Soxhlet Type Extractor
Edouard Batailles, 101 Parke Av., New York, N. Y.

Hydraulic Press Plant
Buckeye Iron and Brass Works, Dayton, Ohio.
Hydraulic Press Manufacturing Co., Columbus, Ohio.
Southwork Foundry and Machine Co., 1168 S. 4th St., Philadelphia, Pa.

Continuous Extractors
Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Rotary Extractors
Wm. Garrigue and Co., 9 So. Clinton St., Chicago, Ill.
J. P. Devine Co., Buffalo, N. Y.
C. O. Bartlett and Snow, 6200 Harvard Ave., Cleveland, Ohio.
Oil Processes Co., Inc., Hamilton at Franklin, Harrison, N. J.
Wurster and Sanger, 5201 Kenwood Av., Chicago, Ill.

Expellers
V. D. Anderson Co., 1935 W. 96th St., Cleveland, Ohio.

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