above and beyond all of this, there was a management philosophy that grasped the importance of these new ideas and re-directed its thinking from traditional channels to encourage the adoption of these ideas. Despite all of the other stimuli, the scientific and technological developments, the fact remains that it was not until top management was able to raise its own thinking that the old-fashioned approaches to design, to processes and process control, were made obsolete.

It is this early recognition and understanding of the basic concepts of automation by the chemical industry management that excites me about the industry's future in today's technological race. I have pointed out previously that the obstacles on the road to the ultimate in automation are not necessarily technological limitations. These obstacles involve the thinking, the attitudes of businessmen. A philosophy of industrial management must be evolved that will correlate the work of the servo engineer, the research engineer, and top management. By its past record the chemical industry's attitude is one that has established a healthy environment for the growth of the contemporary trend toward more automation.

Because and as the result of this, I believe I can envision the chemical plant of the future. It will be a structure more modern, more self-sufficient, and more efficient than we know today. It will not, for example, have two-thirds of its inventory tied up in storage tanks. I believe the application of servo mechanism techniques will eliminate the necessity for maintaining goods-in-process inventories at each stage of the production process. The servo techniques will instead maintain the proper relationships between the various production phases and will permit the system to correct the errors without disrupting the production operations. Obviously under such conditions a reservoir of goods-in-process inventories, standing idle, will not be needed to smooth over the production disruptions. I am sure that the costs of the controls will be offset by this contraction of inventories.

When will this come about? Perhaps not for 10 years, possibly even 50 or 100. The industry knows more about its coming requirements than I do. But the fact remains that newer and more critical processes will need more sensitive control equipment and more advanced concepts of automation. We are confident that we shall be ready for the problems that may arise.

Economics of Cottonseed Extraction

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SINCE the products of the cottonseed industry are so varied and compete in fluctuating markets, any economic analysis is difficult. Furthermore a cottonseed processor is presented with several competing processes to replace hydraulic pressing. Products from each of these processes differ in appearance and other properties from present trade standards. In choosing among these processes, no processor can be guided by generalizations about economics but must take into account the nature of the seed available to him, utility and labor costs in his area, and the acceptance of products in his market. It will appear from this economic analysis that no one process has clear superiority in every situation.

Keator McCubbin

Why Solvent Extraction?

To provide a comparative background on solvent extraction, a brief discussion on economics of soybean extraction is included. For soybeans the case for solvent extraction is easily demonstrated. Solvent extraction can produce by well-established methods 351 pounds of oil per ton of beans, compared with 286 by screw pressing, and at every historical price for oil and meal there is some plant capacity above which investment in a solvent plant can be justified. Since in the soybean industry it is not customary to adjust the meal to constant protein content, the increased value of the product of solvent extraction is calculated as pounds of oil times the difference between oil and meal prices. For example, when meal is 3c a pound and oil is 12c a pound, the increased product value is 65 pounds of oil × 9c, or $5.85 per ton. This is an increase of 6.9% from an original total product value of $84.54.

For cottonseed, solvent extraction to ½% residual oil can produce 364 pounds of oil from a ton of seed, compared with 320 for hydraulic pressing and 330 for screw pressing. Since cottonseed meal is adjusted to a constant protein content with hulls, the increased value of the product is calculated as pounds of oil times the difference between oil and hull prices. With meal at $60 per ton, oil at 12½c per pound, hulls at $20 per ton, and linters averaging 7½c per pound, the gross product value per ton of seed from hydraulic pressing is $85.61, from screw pressing $86.76, and from solvent extraction $90.67. Percentagewise the increase from hydraulic pressing to solvent extraction is 5.9%, and from screw pressing to solvent extraction 4.5%.

When compared in this way, the soybean and cottonseed pictures are not much different, and the same basic incentive exists which has led to almost complete adoption of solvent extraction of soybeans. There is no need to demonstrate to this audience that the major variable in this picture is the price of oil, or, more accurately, oil less meal in the case of soybeans and oil less hulls in the case of cottonseed. For cottonseed, the meal generally leaves solvent plants with 10 to 12% moisture as compared with 7 to 10% moisture in meal from hydraulic or screw press plants. The moisture in raw cottonseed usually averages about 7½%. Therefore a cottonseed solvent plant

TABLE I.
Comparative Economics of Cottonseed Processes Based on Conversion From Hydraulic Pressing

	Plant Capacity, 200 Tons/Day — 200 Days/Year Operation						
	1 Hydraulic pressing	2 Screw press	3 Prepress extraction (all new)	4 Prepress extraction (reconditioned press eqpt.)	5 Direct extraction	6 Filtration-extraction (all new)	7 Filtration-extraction (existing equipment)
Capital investment		$250,000	$620,000	$540,000	$636,000	$640,000	$520,000
Annual Processing Cost							
a) Fixed Charges							
Depreciation at 10%		25,000	62,000	54,000	63,600	64,000	52,000
Interest at 5%		12,500	31,000	27,000	31,800	32,000	26,000
Insurance and taxes at 2½%		6,250	15,500	13,500	15,900	16,000	13,000
Total fixed charges		43,750	108,500	94,500	111,300	112,000	91,000
b) Direct Operating Labor							
Foreman, manhours/day		24	24	24	24	24	24
Cost at $1.50/hr.		7,200	7,200	7,200	7,200	7,200	7,200
Operators, manhours/day		24	48	48	48	48	48
Cost at $1.30/hr.		6,250	12,500	12,500	12,500	12,500	12,500
Helpers, manhours/day		8	8	8	8	8	8
Cost at $1.20/hr.		1,920	1,920	1,920	1,920	1,920	1,920
Total direct labor		15,370	21,620	21,620	21,620	21,620	21,620
c) Maintenance							
Maintenance labor, man-hours/day		8	8	8	8	8	8
Cost at $1.50/hr.		2,400	2,400	2,400	2,400	2,400	2,400
Repair parts (estimated)		3,350	3,900	4,200	3,000	3,000	4,000
Total maintenance		5,750	6,300	6,600	5,400	5,400	6,400
d) Utilities							
Power, KW		375	305	305	250	250	250
Cost at 1.5c/KWH		27,000	22,000	22,000	18,000	18,000	18,000
Steam, lbs./ton		200	530	530	900	680	680
Cost at 80c/1,000 lb.		6,400	17,000	17,000	28,800	21,800	21,800
Water, (Makeup) GPM			13.5	13.5	35	30	30
Cost at 8c/1,000 gal.			310	310	800	690	690
Total utilities		33,400	39,310	39,310	47,600	40,490	40,490
e) Solvent							
Solvent loss, lbs./ton			8.8	8.8	12	12	12
Cost at 3c/lb.			10,560	10,560	14,400	14,400	14,400
f) Total Processing Cost	$160,000	98,270	186,290	172,590	208,320	193,910	173,910
Increase in Processing Costs over hydraulic pressing		−61,730	26,290	12,590	40,320	33,910	13,910
Increased product value							
Lb./ton additional oil		10	44	44	40	40	40
Value at 11.5c/lb.		46,000	202,000	202,000	184,000	184,000	184,000
Net annual increase in manufacturing return from conversion		107,730	175,710	189,410	143,680	150,090	170,090
Net annual increase in manufacturing return per dollar invested		0.43	0.28	0.35	0.23	0.24	0.33
Net annual increase in payout from conversion		132,730	237,710	243,410	207,280	214,090	222,090
Net annual increase in payout per dollar invested		0.53	0.38	0.45	0.33	0.34	0.43

will permit additional meal recovery. This factor was not used in arriving at the data in Table I. For soybeans, the meal and beans have approximately the same moisture content. These oil and meal prices fluctuate widely and every man is entitled to his own opinion about the future, but certainly those in the soybean industry who have converted to solvent extraction have on the whole no reason to regret it on account of low oil prices.

Continuing with the rough comparison, investment in solvent extraction facilities for cottonseed, whether of the prepress or direct extraction type, is somewhat less than the investment in a plant for the same soybean tonnage. Operating costs also are comparable. However compared with soybeans the cottonseed picture is complicated because cottonseed is a by-product of ginning, is not easily transportable, and has peculiar problems of storage, operation, and product quality. Cottonseed is sold in local markets while soybeans are marketed on a national basis. These topics have been discussed elsewhere in this Short Course and need only be mentioned here.

Most small cottonseed plants operate only 200 days a year and therefore cannot expect the return on investment characteristic of the year-round operations experienced by soybean processors. Many of these cottonseed plants are located in areas which cannot support large installations and will always be marginal. The success of the small plants in competition with large installations, which operate 300 days per year, has always depended on local conditions and will continue to do so. This discussion will be confined to plants with a capacity of 200 tons per day and an operating period of 200 days per year. However the procedure outlined in Table I may be used for an economic analysis of larger plants with longer operating periods.

For purpose of economic analysis it will be assumed that all processes, regardless of their present state of development, operate satisfactorily. At any given time the prospective investor will of course make up his own mind about the difficulties he may expect to encounter in getting under way.

It is assumed that all processes are capable of yielding products of equal quality. However the individual processor must decide which process yields the most marketable products.

Investment Payout vs. Manufacturing Return

The processor interested in a new investment will examine it from the two angles of payout and net manufacturing return. Payout is the net additional annual return due to the investment (after deduction of taxes if computable) without deducting depreciation. Payout presents a short-time picture of the business. Net manufacturing return is the additional return due to the investment, after deducting depreciation, and presents a long-time picture of the business.

For convenience in computing fixed charges, a depreciation rate of 10% on all investment will be assumed; interest rate at 5% (although a smaller interest rate is justifiable in calculating net manufacturing return); and insurance plus taxes at 2½% of investment.

Hydraulic Pressing

Other processes will be compared with an existing hydraulic press operation which has been completely written off. The major cost in these plants is for labor, a cost which is increasing constantly. Average hydraulic pressing produces cake containing 5.5% oil.

Screw Press Operation

The advantage of this familiar process lies in the low capital investment and its ability to handle any seed. Its disadvantages are the high residual oil content of the cake, assumed here to be 4.3%, and large power requirements.

Solvent Extraction

Three continuous solvent extraction processes are compared in this paper, namely, prepressing followed by extraction, direct extraction, and filtration-extraction.

Prepress Extraction, Figure 1A. In this process cottonseed is prepared for extraction by rolling, cooking, and prepressing cottonseed meats in a manner similar to that used in screw press plants. Prepressed cake is passed through a cake breaker and then through corrugated rolls. Cake granules so prepared are then extracted in a percolation type of extractor, and the extracted cake is desolventized and cooled. Oil is recovered by evaporation of solvent from miscella in conventional equipment.

The advantage of this process is that it converts any seed, regardless of condition, into an easily handled cake which is extractable to low residual oil content at a low solvent ratio. Its disadvantage is that it requires essentially two separate plants. However this disadvantage appears in proper perspective when it is remembered that every solvent extraction operation requires two separate areas, one for preparation and one for extraction.

A residual oil content of 0.5% in finished meal is regularly realized in prepress plants.

Direct Extraction, Figure 1B. In the direct extraction process, cottonseed dehulled in the usual way is prepared for extraction by mild heating and flaking. Extracted meats are desolventized and cooked, and oil is distilled in conventional equipment.

Essentially this is identical with conventional soybean extraction. The solvent ratio based on seed is about the same as that for soybeans. At its best this process may show somewhat lower operating costs than competing extraction processes, but its disadvantage is its dependence on a source of good seed if operating difficulties are to be avoided. At the present time a residual oil content of 1% in the cake can be expected from this process.

Filtration-Extraction Process, Figure 1C. In the filtration-extraction process devised by the Southern Regional Research Laboratory, dehulled cottonseed meats are prepared for extraction by rolling and

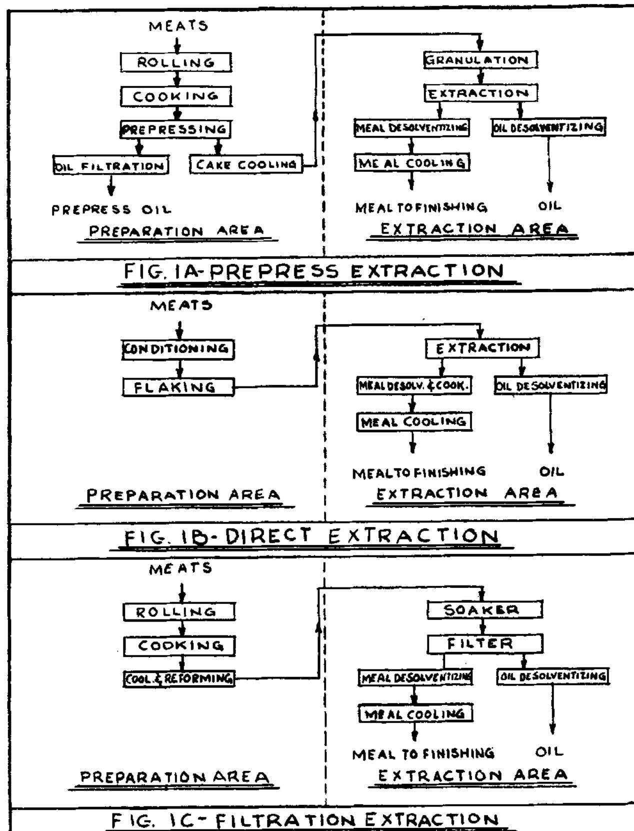

FIGURE 1 - SOLVENT EXTRACTION PROCESSES FOR COTTON SEED

cooking as for hydraulic pressing. Cooled meats are then extracted in the combination of soaker followed by a horizontal rotary filter. Extracted meats and oil are desolventized in conventional equipment.

This process, which is still in the development stage, may operate satisfactorily regardless of seed quality at a considerably lower solvent ratio than is required in direct extraction. It has a special appeal to hydraulic press plant operators, who can salvage much of their preparation equipment. At the present time a residual oil content of 1% in the cake is anticipated.

Economic Analysis

A comparative economic analysis of the different processing methods is presented in Table I for a plant with a capacity of 200 tons per day of seed operating 200 days per year. This analysis is restricted to that portion of a hydraulic press plant which would be replaced by screw press or solvent extraction and would derive the increased manufacturing return and payout to be expected by replacement of that portion. Since numerous assumptions must be made in this analysis, the conclusions from it can only be qualitative but nevertheless make a useful comparison.

Starting with hydraulic pressing, it is assumed that any existing plant is completely written off and that there are no fixed charges other than insurance and taxes. A conventional figure of $4 per ton of seed has been assumed for processing costs, including insurance and taxes, operating labor, maintenance, and utilities directly chargeable to the hydraulic press operation. Supervisory labor and all indirect costs chargeable to the extraction step are, for simplicity, assumed equal in all cases and are omitted from the table.

Capital investment costs given are necessarily approximate but are intended to include all equipment and construction costs for preparation and extraction areas. A suitable building is included for housing preparation equipment; the extraction area is sheltered but not housed. Not included are all items which might reasonably be expected to be found in an existing plant, like boilers, power stations, receiving and storage facilities, meal grinding, and office. A water cooling tower is included in the solvent plants.

In addition to screw pressing and the three solvent processes based on new equipment, two special cases are included in Table I. In the first case there is now available at a considerable reduction in initial investment reconditioned screw press equipment suitable for prepressing. For simplicity, this reconditioned equipment has been depreciated in the analysis in Column 4 at the same rate as new equipment.

In the second special case most hydraulic press operators contemplating conversion to filtration-extraction will be able to use their present rolling and cooking equipment and the building in which it is housed with practically no conversion cost. This analysis is made in Column 7 where, to demonstrate filtration-extraction to the best advantage, the investment in this equipment has been assumed to be completely written off.

Another special case not included in Table I but worthy of mention is the conversion of an existing 200-ton-per-day screw press plant to solvent extraction. The approximate capital investment for the addition of a solvent extraction plant is roughly $400,000, thereby giving a total investment for the entire prepress extraction plant of $650,000. If the processor has a plant which is out of balance with respect to dehulling and delinting equipment, there is the possibility of increased production to about 250 tons per day for this case. However the additional capacity can be utilized only if the processor has improved his competitive position to enable him to obtain more seed. This is a unique case in that it offers increased capacity at a very low cost.

Conventional rates have been used for fixed charges, labor, and utilities. The sum of fixed charges and annual costs of direct operating labor, maintenance, utilities, and solvent is the total process cost from which is substracted the cost of hydraulic press operation. Increased product value is based on 11½c per pound differential between oil and hulls. The subtracting of the differential processing cost from the increased product value gives the annual increase over hydraulic pressing in manufacturing return, to which is added depreciation to get the annual payout increase.

Conclusions

At a differential of 11½c per pound between oil and hull prices all the processes analyzed are attractive investments. Screw pressing pays off well at a lower annual investment and return, and many processors can look to screw pressing as a profitable stepping stone on the way to a prepress extraction plant.

Among the solvent processes there is little difference when they are compared on the basis of all new equipment, and choice of process will likely depend on considerations of performance and product quality. Prepress extraction based on reconditioned equipment and filtration-extraction based on existing preparation equipment, where they suit the need of the individual processor, show improved returns.

Heat Transfer

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THE flow of heat is essentially a very simple thing. If two substances of different temperatures are placed so that heat can flow from the warmer to the cooler, the rate of heat flow will be directly proportional to the temperature difference between the bodies and the cross-sectional area available for transfer and inversely proportional to the resistance interposed. Application of this simple statement is sometimes a bit troublesome.

J. W. Hayward

In a solid body the flow of heat is the result of the transfer of thermal energy from one molecule to another. This process is called conduction. The same process occurs in fluids, but since the molecules are not confined to a certain point, other processes must be considered. In fluids the transfer of heat from one point to another may be effected by carrying the heat with the flow of the fluid. This process is called convection.

All substances are capable of radiating thermal energy in the form of electromagnetic waves and of picking up radiant energy by absorption. This is known as radiation.

Generally in industrial practice the flow of heat to be considered is from a fluid through a solid to another fluid. This involves at least two and sometimes three mechanisms of heat transfer. The heat is transferred from the fluid to the solid primarily by convection and conduction. In the case of boilers and fired heaters the radiation from the gases in the combustion zone to the solid tubes is important. Radiation is always present but often may be neglected. The heat moves through the solid by conduction and from the solid to the second fluid by convection and conduction. Heat transfer may occur either in a steady state, that is, the temperature at a given point does not vary with time or as an unsteady state where the temperature at a given point varies with time, either uniformly in a given direction or periodically increasing and decreasing. For most engineering work steady state conditions apply, and the primary concern is with conduction and convection.

Conduction is the simplest form of transfer. The basic equation for steady state unidirectional conduction is Fourier's:

$$q = -kA \, dt/dL$$