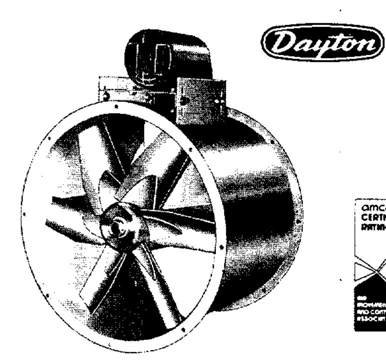
American Institute of Chemical Engineers

STUDENT CONTEST PROBLEM

1988

• AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, 345 EAST 47th STREET, NEW YORK, NEW YORK 10017 •

FIGURE 4. Performance and Cost of Ventilation Fans



- **AMCA Certified Ratings**
- **Handles temperatures up to 200°F**

CERTIFIED RATINGS FOR AIR AND SOUND

Dayton Electric Mfg. Co. certifies that the tubeaxial fans shown herein are licensed to bear the AMCA Seal. The ratings shown are based on tests made in accordance with AMCA Standard 210 and AMCA Standard 300 and comply with the requirements of the AMCA Certified Ratings Program. Performance shown is for units with inlet duct and without outlet duct.

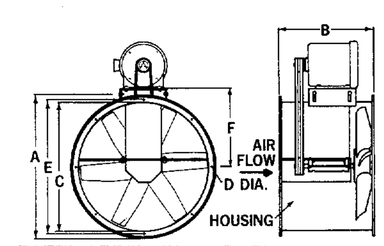
The sound power level ratings shown are in decibels referred to 10^{-12} watt. The sound ratings were obtained in accordance with AMCA Standard 300 test setup No. 4. The sound power A weighted levels Lw(A) were calculated in accordance with AMCA Standard 301. Values shown are the sound power levels at the fan inlet, A weighted.

Tubeaxial fans are designed and built for use as exhausters in paint spray booths, cleaning tanks, mixing rooms, etc., and can also be used in industrial ventilation systems handling temperatures up to 200°F.

Motor, drive belts and sealed ball bearings are isolated from air stream so that hazardous air or vapors can be exhausted without damage to drives or motor.

Permanent prelubricated oversize ball bearings. Bearings are rubber isolated in die formed housing. Precision balanced non-sparking fabricated aluminum fan blades efficiently provide air delivery up to 1¼" SP. Fan housing is iron phosphate processed and finished with acrylic epoxy.

Cast iron double groove fan pulley with malleable split-taper bushing is assembled on fan. Motor, motor pulley, and belts packed separately when fan is ordered complete.



No.	Dimensions in Inches A	B	C	D	E	F	No. of Wings	Shaft Dia.
3C411	27	18	24 5/16	7/16	25¾	16 3/16	6	1
3C412	33⅝	24	30½	7/16	32¼	19¼	6	1 3/16
3C413	37¾	29	34½	7/16	36¼	21⅜	6	1 3/16
3C414	39¾	29	36½	7/16	38¼	22 7/16	6	1 3/16
3C415	45¾	32	42½	9/16	44¼	25 3/16	5	1 7/16
3C416	51¾	36	48½	9/16	50¼	28 5/16	5	1 7/16

Blade Dia.	CFM & Sound Power Lw (A) Decibels at Static Pressure Shown: Free Air	1/8" SP	1/4" SP	1/2" SP	3/4" SP	1" SP	1¼" SP	Fan RPM	HP	Max. BHP*
24"	7915	7615	7285	6555	5655	—	—	1466	1½	1.31
	92	90	91	93	95	—	—			
	9110	8860	8580	7985	7295	6490	—	1688	2	1.98
	95	94	94	95	98	99	—			
	10310	10090	9850	9335	8780	8155	7445	1910	3	2.87
	99	98	97	97	99	101	102			
30"	10955	10415	9815	8395	—	—	—	1030	1½	1.40
	90	89	89	93	—	—	—			
	12190	11710	11180	9990	8485	—	—	1146	2	1.90
	93	94	94	93	95	—	—			
	14040	13630	13180	12220	11105	9740	—	1320	3	2.91
	98	96	96	96	99	99	—			
	16495	16150	15785	14995	14145	13190	12125	1551	5	4.72
	102	101	100	100	100	102	104			
34"	14430	13760	13020	11285	7155	—	—	936	2	1.83
	94	92	92	94	96	—	—			
	16560	15985	15350	13965	12305	7750	—	1074	3	2.78
	100	100	99	99	100	102	—			
	19290	18800	18280	17150	15880	14445	12180	1251	5	4.36
	101	102	101	100	100	102	103			
36"	15255	14455	13570	11430	—	—	—	837	2	1.82
	92	90	90	94	—	—	—			
	17570	16890	16135	14450	12345	—	—	964	3	2.79
	98	99	97	98	100	—	—			
	20650	20080	19460	18135	16605	14825	—	.1133	5	4.53
	100	101	100	99	101	102	—			
42"	21465	20430	19275	16565	—	—	—	746	3	2.76
	90	91	92	95	—	—	—			
	25320	24460	23505	21435	18965	—	—	880	5	4.53
	98	98	98	98	99	—	—			
	29150	28410	27610	25900	23960	21775	18120	1013	7½	6.88
	100	100	101	102	103	103	103			
	33005	32355	31670	30185	28620	26850	24920	1147	10	9.98
	103	104	104	105	106	107	107			
48"	31260	30070	28745	25810	22170	—	—	731	5	5.00
	100	99	98	99	100	—	—			
	35365	34325	33185	30750	27900	24390	—	827	7½	7.25
	102	102	102	101	101	103	—			
	38100	37140	36105	33885	31380	28550	24060	891	10	9.04
	104	104	104	103	103	104	105			

(*) Maximum HP required at air delivery shown. Does not include drive losses.

Fans Less Motor & Drive: Blade Dia.	Stock No.	List	Each	Shpg. Wt.	Fans with 1725 RPM, 230/460V 60 Hz. 3-phase Ball Bearing Motor & Drive — Dripproof: Stock No.	List	Each	Totally Enclosed Fan Cooled: Stock No.	List	Each	Explosion Proof: Stock No.	List	Each
24"	3C411	$486.10	**$324.06**	85.0	7F827	$742.05	**$444.33**	7F830	$748.30	**$448.08**	7F833	$906.95	**$543.08**
					7F828	760.85	**455.59**	7F831	766.05	**458.71**	7F834	938.30	**561.84**
					7F829	770.00	**461.08**	7F832	795.05	**476.08**	7F835	977.70	**585.45**
30"	3C412	725.55	**483.71**	165.0	7F836	988.05	**591.63**	7F840	994.30	**595.38**	7F844	1152.95	**690.38**
					7F837	1003.30	**600.76**	7F841	1008.50	**603.88**	7F845	1180.70	**707.01**
					7F838	1024.30	**613.35**	7F842	1049.35	**628.35**	7F846	1232.00	**737.72**
					7F839	1044.35	**625.35**	7F843	1080.85	**647.22**	7F847	1313.65	**786.60**
34"	3C413	816.45	**544.31**	230.0	7F848	1095.35	**655.90**	7F851	1100.60	**659.02**	7F854	1272.80	**762.15**
					7F849	1113.10	**666.52**	7F852	1138.15	**681.52**	7F855	1320.80	**790.89**
					7F850	1145.85	**686.12**	7F853	1182.35	**707.99**	7F856	1415.10	**847.37**
36"	3C414	849.35	**566.23**	240.0	7F857	1133.25	**678.59**	7F860	1138.45	**681.71**	7F863	1310.70	**784.84**
					7F858	1154.75	**691.46**	7F861	1179.80	**706.46**	7F864	1362.45	**815.83**
					7F859	1174.80	**703.46**	7F862	1211.30	**725.33**	7F865	1444.10	**864.71**
42"	3C415	1188.65	**792.42**	368.0	7F866	1490.50	**892.50**	7F870	1515.55	**907.50**	7F874	1698.20	**1016.87**
					7F867	1525.15	**913.26**	7F871	1561.70	**935.13**	7F875	1794.45	**1074.51**
					7F868	1630.30	**976.21**	7F872	1643.85	**984.34**	7F876	1921.50	**1150.59**
					7F869	1701.00	**1018.56**	7F873	1714.55	**1026.68**	7F877	1981.75	**1186.68**
48"	3C416	1499.05	**999.35**	456.0	7F878	1855.15	**1110.86**	7F881	1891.65	**1132.73**	7F884	2124.45	**1272.11**
					7F879	1950.30	**1167.85**	7F882	1963.90	**1175.98**	7F885	2241.55	**1342.23**
					7F880	2038.80	**1220.82**	7F883	2052.35	**1228.94**	7F886	2319.55	**1388.94**

CONVERSION FACTORS NECESSARY TO COMPUTE SOUND PRESSURE LEVELS [dB(A)] FROM SOUND POWER LEVELS (LwA)

Floor Area Square Feet	Distance to Work Station from Fan: 5'	10'	15'	20'
1000	5	6	7	7
10000	9	12	13	13
20000	10	13	14	15
40000	10	15	16	17

These conversion factors can be used to determine the approximate sound pressure level [dB(A)] for the above listed Dayton tubeaxial fans installed in your plant using the sound power levels (LwA) given above.

To calculate the sound pressure level, subtract the appropriate conversion factor from the sound power level for your fan. The conversion factors shown are based on open areas of factory construction with 20-foot high ceilings. Areas larger than those shown will have a relatively minor effect on sound pressure level. Judgement must be used because details of specific installations will vary considerably. Sound produced by other nearby equipment or machinery is not included in this calculation.

NET WHOLESALE PRICES—W.W.GRAINGER, INC.

FIGURE 3. Viscosity of Distillation Column Bottoms vs. Temperature and Soluble Solids Concentration

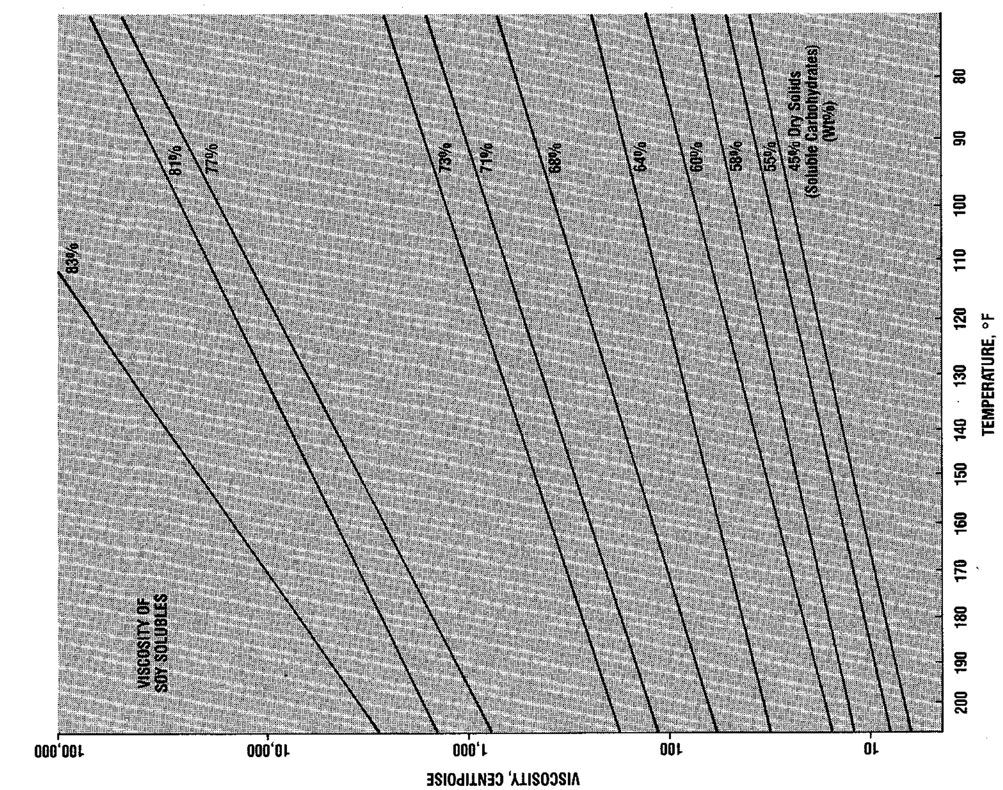
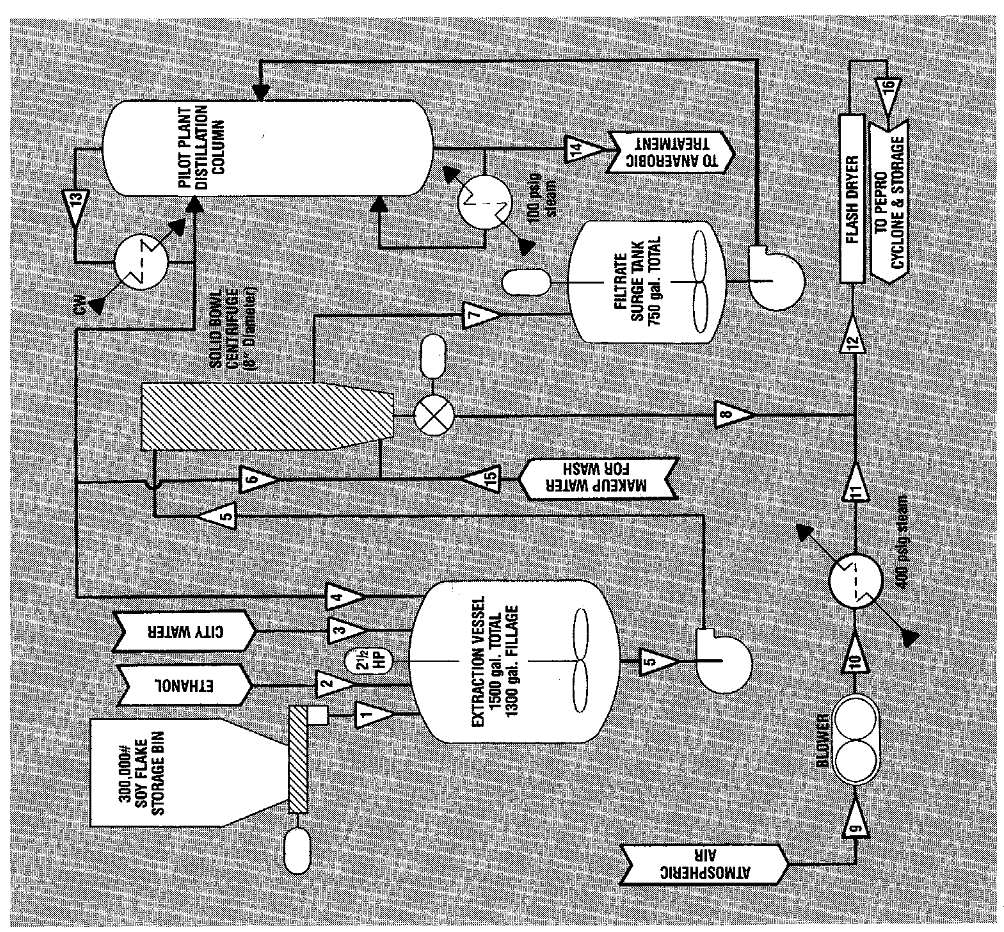


FIGURE 2. Process Flow Schematic for Pilot Plant Soy Flake Extraction Process



1988 AIChE Student Chapters Student Contest Problem

Deadline for Mailing:

Solution must be postmarked not later than midnight, June 1, 1988

Rules of the Contest:

(Revised July 31, 1987)

■ Solutions will be graded on (a) substantial correctness of results and soundness of conclusions, (b) ingenuity and logic employed, (c) accuracy of computations, and (d) form of presentation. Accuracy of computations is intended to mean primarily freedom from mistakes; extreme precision is not necessary.

■ It is to be assumed that the statement of the problem contains all the pertinent data except for those readily available in handbooks and similar reference works. The use of textbooks, handbooks, journal articles, and lecture notes is permitted. In cases where there is disagreement in the data reported in the literature, the values given in the problem have been chosen as being most nearly applicable.

■ Students may use any available commercial or library computer programs in preparing their solutions. Students are warned, however, that physical property data built into such programs may differ from data given in the problem statement. In such cases, as with data from other literature sources, values given in the problem statement are most applicable. Students using commercial or library computer programs or other solution aids should so state in their reports and include proper references and documentation. Students are further advised that the problem can be solved without the use of sophisticated computer programs. Judging is based on the overall suitability of the solution, not on skills in manipulating computer programs.

■ The Student Contest Problem is designed to be solved by individual chemical engineering students working entirely alone, and it is judged on that basis. There are, however, other academically sound approaches to using the problem. The following confidentiality rules therefore apply:

1. *For students whose solutions may be considered for the contest:* The problem may not be discussed with anyone (students, faculty, or others, in or out of class) before or during the period allowed for solution. Discussion with faculty and students at that school is permitted only after complete final reports have been submitted to the chapter counselor.
2. *For students whose solutions are not intended for the contest:* Discussion with faculty and with other students at that school who are not participating in the contest is permitted.
3. *For all students:* The problem may not be discussed with students or faculty from other schools, or with individuals in the same school who are still working on the problem for the contest, until after June 1, 1988. This is particulary important in cases where neighboring institutions may be using different schedules.

Submission of a solution for the competition implies strict adherence to these conditions.

■ A period of not more than thirty consecutive days is allowed for completion of the solution. This period may be selected at the discretion of the individual counselor, but in order to be eligible for an award a solution must be postmarked not later than midnight, June 1, 1988.

■ The finished report should be submitted to the chapter counselor within the thirty-day period. There should not be any variation in form or content between the solution submitted to the chapter counselor and that sent to the AIChE office. The report must be suitable for reproduction, that is, typewritten or computer-generated. Tables must be written in ink. Each counselor should select the best solution or solutions, not to exceed two, from his chapter and send these by registered mail to the institute.

■ Two copies of the solution(s) must be accompanied by a letter of transmittal giving only the contestant's name, school address, home address, home telephone number, and student chapter, lightly attached to the report. This letter will be retained for identification by the Secretary of the Institute. The solution itself must bear no reference to the student's name or institution by which it might be identified. In this connection, graph paper bearing the name of the institution should be avoided. Original manuscript(s) must remain in the possession of the student chapter counselor, or faculty member, sponsoring the student(s).

As soon as the winners have been notified, original manuscripts for first, second, third and honorable mention categories must be forwarded to the office of the Executive Director and Secretary as soon as possible.

J.F. Mathis
Interim Executive Director
American Institute of Chemical Engineers
345 East Forty-seventh Street
New York, New York 10017

1988 AIChE Student Contest Problem:

Preliminary Design of an Edible Soy Protein Facility

Introduction

Soybean meal (the physical form is flakes) is the residual material remaining after oil has been extracted from soybeans. It is a product relatively high in protein, and has long been used for animal feeds but, because of flavor and texture problems, has not been widely used in human foods. However, a process has been developed which uses ethanol extraction to render the meat palatable.

The composition of soybean solids after they have been flaked in preparation for oil extraction is given in Figure 1-A. After the oil has been extracted with hexane and the flakes have been dried the composition is that given in Figure 1-B. The deoiled flakes can be made suitable for human consumption by using a proprietary ethanol extraction process which removes carbohydrates and other solubles along with objectionable flavors, to yield a nearly bland (flavorless) soy protein concentration (SPC) product of the composition given in Figure 1-C.

Statement of Problem

You are an engineer in the Protein Power (PROPO) Division of Agricultural Processing Corporation, a firm which is proud of its expertise in the processing of agricultural products. As a member of the Corporate Engineering Department your assignment is to do a preliminary design and economic analysis of a new soy protein concentrate facility using an ethanol extraction process which PROPO R&D has developed. Eighteen months ago, following the completion of pilot plant studies, a semiworks operation with a capacity of 680 lbs product/hour was started up. (A flow sheet and process description for the semiworks process are attached.) The market has now been developed to the point that the construction of a 50 MM lb/yr facility is being investigated.

The finished edible product will be conveyed across the fence to the PEOPLE PROTEIN (PEPRO) packaging facility next door. Your marketing people want from CED the selling price of the edible soy protein product necessary to achieve the corporate hurdle rate of 15% IRR for the 50 MM lb/year project.

The new facility is to be built near Decatur, Illinois, on the site of the existing semiworks. All existing equipment from the semiworks plant will be available for the new facility, should any be applicable.

American Institute of Chemical Engineers, Inc.
345 East Forty-seventh Street
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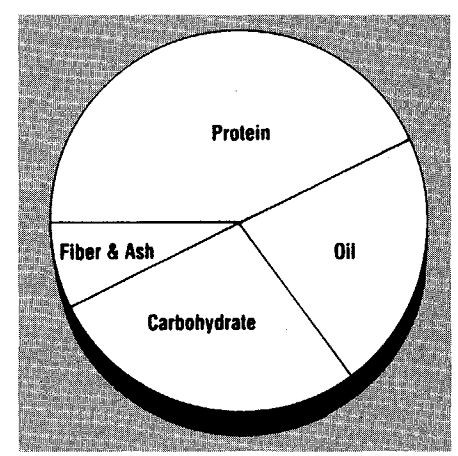
TABLE 2. Material Balance for Pilot-plant Soy Flake Extraction Process
NOTE: All Flow Rates in lb/hr unless otherwise noted.

COMPONENT STREAM #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
MATERIAL BALANCE FOR SOLID PHASE																
Protein	450	0	0	0	450	0	0	450	0	0	0	450	0	0	0	450
Carbohydrates*	300	0	0	0	170	0	0	170	0	0	0	(174)	0	0	0	(174)
Ethanol	0	0	0	0	30	0	0	30	0	0	0	30	0	0	0	10
Water	84	0	0	0	30	0	0	30	0	0	0	30	0	0	0	15
TOTAL—SOLID PHASE	834	0	0	0	680	0	0	680	0	0	0	680	0	0	0	645
MATERIAL BALANCE FOR LIQUID AND (VAPOR) PHASES																
Protein	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbohydrates*	0	0	0	0	130	0	126	4	0	0	0	4	0	126	0	0
Ethanol	0	340	0	3,190	3,500	340	3,532	308	0	0	0	(308)	(14,240)	2	0	(328)
Water	0	0	3,086	360	3,500	40	3,532	308	(140)	(140)	(140)	(448)	(1,600)	3,132	300	(463)
Air	0	0	0	0	0	0	0	0	(7,000)	(7,000)	(7,000)	(7,000)	0	0	0	(7,000)
TOTAL—L. AND (V.) PHASES	0	340	3,086	3,550	7,130	380	7,190	620	(7,140)	(7,140)	(7,140)	(7,448)	(15,840)	3,260	300	(7,483)
TOTAL FLOWS FOR ALL PHASES COMBINED																
TOTAL—ALL PHASES	834	340	3,086	3,550	7,810	380	7,190	1,300	7,140	7,140	7,140	8,128	15,840	3,260	300	8,128
OTHER STREAM DATA																
Flow, GPM (CFM)	—	.85	—	8.9	17.4	0.95	16	—	(1,500)	(940)	(1,450)	(1,100)	(3,800)	6.6	0.6	(1,830)
Temperature °F	70	80	80	80	140	110	140	140	70	170	410	170	170	212	80	170
Pressure, PSIG	0	0	0	0	5	0	0	0	0	14	10	10	0	0	0	0

*Carbohydrates includes non extractables such as cellulose and ash.

FIGURE 1. Protein Concentration Process

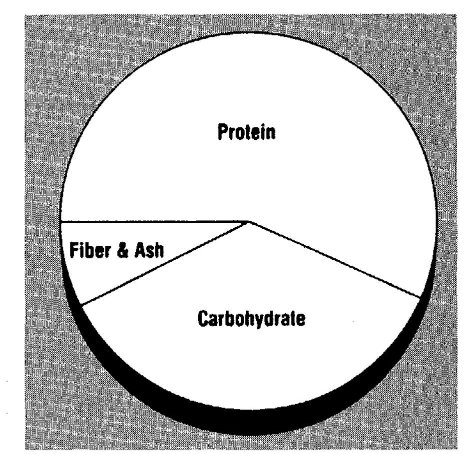
1A: *Dehulled Beans 100 lbs.



Composition of a dehulled soybean moisture free bases.

Protein 42.8% **Fiber** 2.0%
Oil 22.0% **Ash** 5.0%
Carbohydrate 28.2%

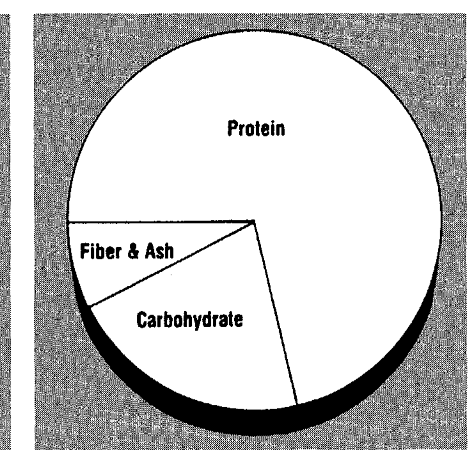
1B: *Defatted Flakes 75 lbs.



Composition of defatted flakes moisture free bases.

Protein >56.5% **Fiber** <2.2%
Oil <.7% **Ash** <5.0%
Carbohydrate <35.6%

1C: *SPC 62 lbs.



Composition of soy protein concentrate moisture free bases.

Protein >70.5% **Fiber** <2.9%
Oil <.4% **Ash** <5.0%
Carbohydrate <21.2%

*Theoretical yield:, as is moisture.

4. A utilities summary showing users (or generators) of utilities, tabulated by equipment.
   Steam (1,000 lb/hr) at each pressure level
   Electricity (KW)
   Cooling water circulation (gpm)
5. A cost summary for the selected design, listing the capital cost of each piece of equipment and the total installed plant cost. Also include an operating cost summary broken down into utilities, chemicals, labor and maintenance, etc.
6. An explanation for your choice of design addressing in particular why your design is the economical optimum. Identify the two or three independent parameters which affect the economic bottom line the most and explain how you determined the optimum values. Keep in mind that you should address both quantitative and qualitative aspects of economic optimization.
7. A summary of the cash flow calculations in the tabular format presented on pages 314 and 315 of reference 1.

E. Appendix
The appendix of the report should include an explanation of all assumptions made and calculation methods used. Calculations, graphs, tables, etc., necessary for a complete understanding of your solution should be included.

References

1. Peters, M.S. and Timmerhaus, K.D., *Plant Design and Economics for Chemical Engineers,* Third Edition, McGraw-Hill (1980).
2. Ind. & Eng. Chem., V. 43, No. 3, 709 (March, 1951).
3. Null, H.R., *Phase Equilibria in Process Design,* Wiley-Interscience, New York (1970).

Table 1. Vapor Composition Data for Ethyl Alcohol-Water at Various Pressures
(Experimental data)

Pressure, Lb/Sq Inch Gage	Temp., °C.	Ethyl Alcohol in Liquid Wt. %	Ethyl Alcohol in Liquid Mole %	Ethly Alcohol in Vapor Wt. %	Ethly Alcohol in Vapor Mole %	Activity Coefficient, Calcd. Ethyl Alcohol	Activity Coefficient, Calcd. Water
27	127.6	1.9	0.7	20.5	9.2	7.04	1.05
	125.9	2.5	1.2	23.7	11.0	5.12	1.09
	120.6	11.8	5.0	55.4	32.7	4.15	1.00
	114.0	26.0	12.1	68.0	45.4	3.02	1.09
	112.0	31.0	14.9	70.0	47.8	2.77	1.15
	112.5	39.4	20.3	71.8	50.0	2.09	1.16
	110.0	54.2	31.6	78.1	58.2	1.69	1.22
	107.8	75.3	54.4	83.4	66.3	1.20	1.60
	107.5	78.0	58.2	84.4	68.0	1.16	1.67
	...	78.3	58.6	84.2	67.6	...	...
	107.3	85.9	70.5	89.0	76.1	1.08	1.78
	107.3	87.3	72.9	90.0	77.9	1.07	1.79
	107.0	91.1	81.7	93.0	83.9	1.03	1.95
	104.8	98.4	96.0	98.4	96.0	1.10	2.42
60	141.8	6.7	2.7	41.9	22.1	5.27	1.08
	133.2	29.3	13.9	69.3	44.6	2.61	1.09
	131.2	36.1	18.1	70.1	47.8	2.27	1.17
	129.0	48.2	26.7	74.5	53.3	1.83	1.24
	128.9	49.9	28.1	74.6	53.5	1.75	1.27
	127.2	66.4	43.6	79.4	60.1	1.33	1.47
	126.3	74.5	53.3	82.0	64.0	1.19	1.64
	125.0	86.3	71.1	89.0	76.0	1.10	1.84
	125.0	88.4	74.9	89.8	77.5	1.06	1.99
	124.6	98.3	95.8	98.0	95.0	1.00	2.51
	124.7	99.7	99.2	99.2	98.2	1.00	...
90	151.8	12.3	5.3	51.5	29.3	3.86	1.08
	150.7	12.8	5.5	54.0	28.9	2.67	1.09
	146.0	28.7	13.6	66.4	43.6	2.57	1.10
	145.5	31.0	14.9	67.6	44.9	2.46	1.11
	142.8	42.6	22.5	71.1	49.0	1.90	1.12
	140.5	55.0	32.3	75.1	54.1	1.55	1.33
	140.2	56.1	33.1	75.5	54.6	1.53	1.35
	137.1	81.2	62.8	85.3	69.4	1.12	1.78
	137.6	87.6	73.4	89.3	76.5	1.05	1.89
	136.0	89.5	76.9	90.5	78.9	1.08	2.05
	135.8	99.3	98.2	99.2	98.0	0.95	2.40
125	158.8	23.7	10.8	62.6	39.5	2.84	1.09
	153.5	38.1	19.4	69.2	46.7	2.14	1.22
	151.3	52.5	30.2	72.5	50.7	1.57	1.39
	150.7	54.5	32.8	74.5	53.3	1.54	1.38
	150.7	53.4	33.6	74.3	53.0	1.50	1.41
	148.0	78.1	58.2	83.2	65.9	1.15	1.74
	147.5	81.6	63.4	84.7	68.4	1.11	1.87
	147.3	89.3	76.5	90.4	78.6	1.06	1.99

Process Description

The process flow diagram for the semiworks operation is given as Figure 2.

Extraction

The semiworks extractor is a 1500 gallon (6′ diameter x 7′ st. side, 150 gal heads) agitated vessel. It is important that the flakes drop onto the free surface of the liquid and that the slurry effluent overflows out the side of the vessel opposite to the flake inlet so that no flakes short circuit the vessel. A baffle should extend down (to within 20% of the vessel diameter of the vessel bottom) into the liquid between the inlet and outlet to also prevent short circuiting and obtain as much plug flow as possible. The vessel should be scaled up to give equal residence time and the agitator should be scaled up on equal power per unit of slurry volume to give equal solids suspension. The 5 hp agitator on the pilot plant extractor is fully loaded by the 4-bladed (30″ diameter at 115 rpm) pitched blade turbine impeller on the agitator.

Centrifugation

An 8″ diameter x 32″ long solid bowl centrifuge was used in the pilot plant. Washing was done on the centrifuge very successfully. A capacity test on this machine in the semiwork demonstrated 1,100 lb/hr of flakes processed successfully. As explained in the Equipment Design and Cost section, there are four surplus 12″ x 48″ machines available which, after they are refurbished, should be adequate to handle the full-scale plant load. The centrifuges can be scaled up on the basis of bowl area to determine the production capabilities of a particular machine.

Distillation

The pilot plant distillation column with bubble cap trays is thought to be somewhat oversized. We don't have details about this equipment. You had best design a new system. The column bottoms contain the extracted carbohydrates (primarily sugars). The viscosity of the bottoms stream as a function of dry solids* concentration and temperature is given in Figure 3. Up to about 60-65% dry solids concentration the VLE for the soy solubles-alcohol-water solution is essentially the same as for water-ethanol. (See Table 1, from reference 2). Above 60-65% solids the assumption of an ideal solution of volatiles and dry solids fits the VLE data very closely with an average molecular weight of 350 for the soluble dry solids. The VLE for ethanol-water is presented in Table 2 from reference 2. The VLE data for ethanol-water are also presented and analyzed in detail on pages 102-109 of reference 3.

Flash Dryer

The semiworks dryer is a tubular flash dryer with a residence time of 2 seconds. A flash dryer is a drying system which uses the drying fluid (typically air) as the conveying medium to move material through the dryer. Normally this type of dryer works well for powders which convey easily in a gas. In the present case the drying medium is a mixture of nitrogen, oxygen and superheated ethanol. The gas phase is heated through a steam coil; feed is introduced into the hot gas and the mixture moves through the dryer to the product collection device. Retention time of the product in the hot gas is typically 1 to 5 seconds. Following separation from the dried product, the gas phase passes through a condenser where the solvent is removed, and the gas is often then cycled through a fan to the heating coils.

Flash dryers have the advantage of being fairly simple in operation and construction, and are likely to be the dryer of choice where the wet product can be dispersed into a gaseous conveying medium, where primarily surface moisture is being removed and where separation of the dried product does not pose problems.

Conveying velocities of 4,500 ft/min are needed to keep the flakes suspended in a horizontal dryer. PEOPLE PROTEIN will supply the cyclone and baghouse necessary for them to separate the flakes from the drying and conveying gas and they will send the conveying gas to their boiler to recovery the energy value of the ethanol and to minimize the release of hydrocarbons to the atmosphere.

Safety Considerations

The extraction vessel and other process equipment, except for the distillation equipment, will be located in the soy feed building which already has explosion proof electrical because of dust hazards; however, with the addition of ethanol, ventilation will have to be added to quickly remove any alcohol spills. Our safety department recommends adequate ventilation of six air changes per hour throughout the 100′ x 100′ x 40′ (at roof wall) x 60′ (at ridgepole) gable roof building. Specifications of tubeaxial fans are given as Figure 4, taken from the fall 1986 W.W. Grainger, Inc. catalog. You should use at least three fans total and design so that the loss of one fan will still give adequate ventilation. The ventilation air will have to be heated. There are already low pressure steam heaters in the building which are adequate to keep the building temperature above 50°F. You need to assume that steam is required to heat the ventillation air from 30° to 50°F for five months of the year in our Central Illinois location.

The semiworks flash dryer uses hot air. It is located outside, thus any explosion hazard is minimized. You should check the design and determine if the dryer operates within ± 40% (2.8% to 27V%) of the explosive range (3.9% to 19V% for ethanol vapors in air). If it does, you had best design the dryer to operate on superheated ethanol rather than hot air. The superheated ethanol will be separated from the flakes in a cyclone baghouse arrangement; PEPRO will fund 50% of a project to install a blower and piping to return the vapors back to PROPO for reuse as the drying medium; however, they will not purchase any equipment for returning condensed liquid because they believe the economics favor burning the alcohol, which is removed from the centrifuge cakes, in their boiler because they are paying $4.00/MM Btu for natural gas for the next 10 years. (PEPRO proposes to pay us $4.00/MM Btu for ethanol for its fuel valve.) This conclusion in perhaps doubtful. If superheated alcohol is used as the drying gas, the excess ethanol vapors can also be condensed and returned to our facility. The distance from our soy flake building to the PEPRO processing building is 200 ft. If the condensed alcohol is returned, we will be required to purchase the condenser, pump and piping needed to condense and return the alcohol to one of our 100,000 gal alcohol storage tanks.

Raw Materials

Soy Flakes

The source of the deoiled soy flakes is a 300,000 lb capacity storage silo in our GROW POWER® animal feeds plant. There is already a spare variable speed screw feeder on the bottom of the bin, located about 30 ft off the floor, with sufficient clearance underneath so that the extraction vessel can be readily placed underneath. The screw feeder was originally designed for 100 MM lb/year so it will be adequate for our current purposes.

The price of the soy flakes as an animal feed component is now rather depressed at $140/ton. Ron James in GROW POWER marketing

*Dry solids are the residue remaining after the solution is oven dried to remove all volatiles.

projects a $140/ton price through 1990 with a 6%/year escalation thereafter.

Ethanol

We have agreements with the Feds to use our POWER ALCOHOL as makeup alcohol because PEPRO will send the gases off the discharge of the flash dryer to be burned in their plant boiler (or we will use superheated ethanol vapor to supply heat to the flash dryer). Our POWERAL contains 0.2% water and except for that is essentially pure ethanol.

We are now sold out of POWERAL, thus the incremental opportunity cost of using it is our netback* selling price of $1.00/gal. Dean Risk in POWERAL sales expects for us to be sold out through 1991 but that in 1992 through 2000 we will have excess capacity and then the opportunity cost of using ethanol will be its incremental manufacturing cost. He expects the sales price of ethanol will escalate at about 4%/year through 1991. The current incremental manufacturing cost for producing POWERAL is $.72/gal; escalation of 5%/year is expected for the next dozen years.

City Water

The current cost for city water is $0.49/100 ft³ with planned increases of 10% in 1990, 10% in 1994 and 10% in 1998.

Other Operating Costs
(All escalated at 5%/year)

Operating Labor

Two operators per shift (24 hour operation) at $13/hr.

Administrative

20% of operating labor.

Direct Supervision and Clerical Labor

15% of operating labor.

Maintenance and Repairs (Labor, Supervision and Materials)

5% of replacement capital.

Plant Overhead

50% of operating labor, supervision and maintenance.

Operating Supplies

15% of maintenance and repairs.

Laboratory Charges

Negligible.

Local Taxes and Insurance

3% of depreciable capital.

Distribution and Selling

1/2 person at $70,000/year per person; in 1988.

Research and Development

1/2 person at $100,000/year per person; in 1988.

*Selling price, FOB Decatur, Illinois, minus all incremental costs of production.

Utilities
(Escalated at 4% year)

	15 PSIG	100 PSIG	400 PSIG
Electricity[1]:			$0.045/KWH
Steam[2]:	$3.20/M lb	$5.00/M lb	$6.00/M lb
Cooling Tower Water[3]:			$0.15/M gal
Compressed Air:			$0.10/M SCF
Waste Treatment Load and Cost[4]:			$0.00*
Steam Condensate (@212°F)			Free up to 100 gpm

1. When the installed motor horsepower is known use the theoretical KW required assuming that the motor will be underloaded sufficiently to offset motor and drive efficiency and power factor. When the user power requirements are known (as for calculated compressor power required) then use a motor and drive efficiency of 90% and a power factor of 0.85. The electrical requirements for the drive motor is the theoretical usage of the user divided by the product of the efficiency and the power factor.
2. Steam can be exported into the steam system from any project with resultant credit.
3. 10°F rise.
4. Methane generated by anaerobic system will pay for other treatment costs.

Installed Cost

For evaluation grade capital estimates, such as the one you are now doing, the "Lang" factor method applied to individual process equipment items (see Ref. 1, p. 181) is our recommended approach. Appropriate "Lang" factors are:

Fractionating Columns (applied to equipment purchase cost)	4.6[1]
Fractionating Columns (applied to "field" installed cost as given in Fig. 14-28, Ref. 1)	2.5[1]
Centrifuges	2.5[1]
Heat Exchangers	4.0[1]
Compressors	2.5[1]
Reactors and Agitated Vessels	4.0[1]
Other Equipment	4.0[1]

[1]These "Lang" factors times the purchased equipment or system cost gives the total depreciable capital investment (including all piping, instrumentation, engineering, etc.) associated with the process equipment item.

Equipment Design and Cost

Heat Exchangers

For overall heat transfer coefficients refer to pages 650-652, Ref. 1. The following overall coefficients are applicable:

Hot Fluid	Cold Fluid	Overall Coefficient Btu/hr ft² °F
Steam	Air	8
Steam	Ethanol Vapor	8
Steam	Column Bottoms	50
Condensing Ethanol	Cooling Water	100
Condensing Ethanol	Boiling Water	150

Use shell-and-tube fixed tube sheet, with expansion joint, 304 SS heat exchangers. 1979 purchase costs are given in Figure 14-15, p. 670, Ref. 1.

Pumps

For 1979 costs and power requirements see Figure 13-40, Ref. 1. Use 316 stainless steel.

Blowers

Use Figure 13-46, Ref. 1 for cost. Straight lobe units are applicable.

Solid Bowl Centrifuges

Four P-4400 Sharples solid bowl centrifuges (12" x 48" machines with 75 hp motors) are available as surplus within our company. They will be completely renovated for $65,000 each. One should be used as a spare. The replacement cost of these machines is $210,000 each.

In our soy operations with water-soy flake slurries these machine each handle at least 2,500 lb/hr of solids at the slurry concentration in the extraction vessel.

Multiple Sharples will be required. They should be installed in parallel with a rotary valve under each solids discharge port with each discharging directly into the flash dryer feed ports.

Flash Dryer

We have just purchased three conveying line flash dryers all of about 150 ft in length. The total installed cost including engineering and everything else, was $210,000 for a 24" unit, $307,000 for a 16" unit and $450,000 for a 12" unit, all of 100 ft.³ volume. You can reasonably interpolate or extrapolate the data from a 6" to a 36" size, with the installed cost varying as the 0.5 power of the dryer volume.

Cost Indices
(See Ref. 1, p. 159)

To update cost data for process equipment use the Marshall and Swift equipment cost index (see Chem. Eng., p. 7, March 16, 1987).

Year	Index	Year	Index
79	599.4	84	780.4
80	659.6	85	789.6
81	721.3	86	797.6
82	745.6	87	806*
83	760.8	88	815*

*Projected

Economic Analysis[1]

H.H. Price of our sales department wants the required selling price to obtain an IRR of 15% on invested capital for the flakes we are air conveying out of our flash dryer over to PEPRO. He along with C.B. Bean of our financial department have requested that the analysis be done on the following basis.

Start-up Date:	1/1/89
Life of Project:	10 Y
Income Tax Rate (ITR):	37%/Y
Depreciation Schedule: Current IRS—14%, 24%, 17%, 12%, 11%, 11%, 11% for years 1 through 7.	
Sales Price Escalation: '88 through '90, 0%/Y; '91 through '98, 5%/Y	
Investment Tax Credit:	0%
Value of business at end of 10th year: In perpetuity value[2]—ACI_{11} (1-ITR)/IRR	

1 The recommended format for presenting discounted cash flow calculations is given on pages 314 & 315 of Ref. 1.

2 In perpetuity value is determined based on the value of the continuing business at the end of the economic analysis life. The value before discounting is the annual net cash income in year 11 (ACI_{11}) plus any salvage value (assumed zero for this analysis) times (1—Income Tax Rate), because we pay taxes on the sale of the business, divided by the interest rate of return (IRR).

Final Report Format

A. Cover letter or transmittal document.
B. Introduction: Give a concise statement of the problem, covering background and objectives.
C. Summary: Submit a brief description of work performed in your evaluation, and your conclusions and recommendations.
D. Technical Information:
   1. A process flow diagram of the process including the major process controls.

      Assign numbers and names to all equipment and label streams with numbers on the flow sheet. These numbers should be used to identify equipment and streams in any table and discussion.
   2. A material balance table showing the following for each stream:
      - Temperature (°F)
      - Pressure (psia)
      - Component mass flow rate (lb/hr)
      - Total mass flow rate (lb/hr)
      - Total volumetric flow rate (gpm for liquids and CFM for gases)
      - Viscosity for liquid streams
   3. An equipment list for the plant. The list should include the following information for each equipment item in addition to its name and number.

Equipment Type	Mimimum Required Information
Compressors	Pressure and temperature at inlet and outlet Efficiency Energy consumption, in brake horsepower Fluid composition and properties
Heat Exchangers	Duty Area Stream temperatures Temperature difference (corrected) Pressure at inlet and outlet Fluid composition and properties Exchanger type and materials of construction
Vessels	Cylindrical section length or height Operating temperature and pressure
Distillation	Diameter and height
Agitators	Motor horsepower Impeller Type Material of Construction
Columns	Mass flows in and out Type of internals, with specifications (i.e., number, spacing, and type of trays) Operating temperature and pressure
Centrifuges	Type Motor Bowl diameter and length