Gals. cooling water/hr. 3,559 × 1,021/60.5 × 8.33 7,210
Cost of cooling water/day 7,210 × .10 × 24/1,000 .... $17.30
Cost of steam/day 4,790 × .40 × 24/1,000 .... 46.00

Costs

Aluminum tubes will be the most economical. They have a life $33\frac{1}{3}$ per cent less than that of copper tubes but they also have

TOTAL INVESTMENT

	No. of effects		
	1	2	3
Evaporator bodies (approx.)	$11,600	$23,200	$34,800
Aluminum tubes—2 sets (4 yrs.)	480	1,078	1,692
Base cost	$12,080	$24,278	$36,492
Condenser—8 per cent of base in 1 (in prop. to water used)	$966	$485	$332
Vac. pump, liquor pumps, etc. 20 per cent of base cost	2,416	2,416	2,416
Overall equipment cost	$15,462	$27,179	$39,240
Installation, pipes, foundations, lagging, etc. 25 per cent overall	$3,866	$6,795	$9,810
Total investment	$19,328	$33,974	$49,050
Expenditure over that of first effect		14,646	29,722

SUMMARY OF CHARGES TO EVAPORATION PER DAY, 100 OPERATING DAYS PER YEAR

	No. of effects		
	1	2	3
Steam cost	$116.60	$62.90	$46.00
Cooling water	50.40	25.30	17.30
6 per cent interest on investment	11.60	20.39	29.43
3 per cent for taxes and insurance	5.80	10.20	14.72
Labor—$5 per shift	15.00	15.00	15.00
6 per cent of init. investment—maintenance	11.60	20.39	29.43
Depreciation of added capital expenditure—25 per cent per yr.		36.62	74.30
	$211.00	$190.80	$226.18

an initial cost 55 per cent lower. In a period of 4 years a replacement would be necessary with either.

Although KA_2 lasts $2\frac{1}{2}$ times as long as aluminum it also costs about 8 times as much and is therefore out of the question.

Even with the stipulation that the added capital expenditure over that of a single effect be written off in 4 years the use of a double effect evaporator results in a net saving of $20.20 per day. The double effect should therefore be used.

A.I.CH.E. ANNUAL STUDENT COMPETITION

FOREWORD

The third annual student competition was sponsored in 1934 under the direction of the Committee on Student Chapters, A. McLaren White of the University of North Carolina, Chairman, and the Sub-Committee on Awards—Professor T. K. Sherwood, Massachusetts Institute of Technology, Chairman; Drs. Thomas H. Chilton and Allan P. Colburn, E. I. duPont deNemours Company, Wilmington, Delaware.

Thirty-five solutions were submitted representing seventeen chapters. The rules of the competition preclude submission of more than three solutions from any one chapter.

On the recommendation of the Committee on Awards Council awarded prizes as follows: 1st prize of $100.00 to Robert V. Lukes, University of Illinois, Urbana, Illinois; 2nd prize of $50.00 to Scott Lyon, Ohio State University, Columbus, Ohio; and 3rd prize of $25.00 to Waldemar A. Schmidt, Oregon State Agricultural College, Corvallis, Oregon. Through the courtesy of Mr. James S. Thompson, Vice-President of the McGraw Hill Book Company 4th and 5th prizes of copies of Perry's Handbook of Chemical Engineering were awarded to Albert E. New, University of North Carolina and David C. Grahame, University of Minnesota, respectively.

As is customary the 1st prize winning solution is published in the Transactions.

FREDERIC J. LEMAISTRE,
Secretary

CONTEST PROBLEM

1934

NATIONAL STUDENT COMPETITION SPONSORED BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS UNDER THE DIRECTION OF THE COMMITTEE ON STUDENT CHAPTERS
(Open to Undergraduates Only)

Statement

The plant proposes to install filters, either of the chamber or of the leaf type, to handle 30,000 gallons per day of a slurry yielding a homogeneous cake (no filter aids are necessary). A test on a small filter press having a cross section of 1 sq. ft. shows that 37 gals. of slurry are filtered in 7 hrs., 10 min., when operating in such a way that $18\frac{1}{2}$ gal. of the filtrate came through at constant rate and the remainder at a constant pressure. During the operation at constant filter rate, the pressure is increased gradually to 60 lbs./sq. in. gauge, which is the pressure employed in the subsequent constant pressure operation. The resulting cake fills a 1 in. distance frame (i.e., 1 sq. ft. of frame or actually 2 sq. ft. of cloth, giving a cake thickness of $\frac{1}{2}$ in. on each filter cloth).

When installed, the presses are to operate at constant rate until the pressure has reached 50 lbs./sq. in. gauge, after which the pressure is maintained constant for the remainder of the cycle. It will be assumed that the rate, as cubic feet per hour per square foot of cloth, during the constant rate period, will be 50% greater than that prevailing during the constant rate portion of the test described, and that the coefficient of compressibility "s" (see Walker, Lewis & McAdams, second edition, page 363) may be taken as 0.1. It is proposed to wash the cake with water equal in volume to one-third of the volume of the filtrate after each filtering cycle. With the chamber press this will be done from one filter leaf to the next through the entire cake thickness, but in the leaf filter in the same direction as the filtrate is passed. Time for cleaning and reassembling will be 2.5 hours per press for the chamber type, and 45 minutes per press for the leaf type. Supervision will be independent of press size and type, but labor for cleaning costs 60c/hr./press. The maximum size of single units of either type will be 900 sq. ft., and when two or more presses are necessary they will be of equal size. The installed first cost per sq. ft. of filtering area is given below:

Size, sq. ft.	100	300	500	700	900
Chamber	$4.90	3.00	2.50	2.30	2.10
Leaf	14.00	11.00	9.60	8.50	7.50

Fixed charges may be taken as 30% per year of 330 days and operation 24 hours per day. Filter cloth costs 11 cents per sq. ft., and may be cleaned 60 times.

Specify the optimum size and operating cycle for (a) the chamber press, and (b) the leaf type.

Calculate the difference in annual costs of the most economical installations of each type.

NOTE: It should be noted that for a filtration conducted as described, the integrated filtration equations given in Walker Lewis & McAdams, 2nd Edition, page 366, cannot be applied directly but must be derived from the differential equation with substitution of the appropriate limits.

Method of Presentation

The solution of this problem should be presented as a report recommending the type and size of filter press to be purchased. In grading reports significance will be given to the form of presentation as well as to the accuracy of the assumptions and computations. Assumptions made should be clearly indicated.

Assume that the decision on expenditure will be made by an executive who has had technical training but is not familiar with modern chemical engineering developments. This executive will require that his technical assistant check the accuracy of the assumptions, calculations, and results in the report. However, in weighing the recommendation and reaching a decision he wants to assure himself personally of the basis for computation and of the validity of the economic method employed. His available time is limited and not more than three minutes of his attention should be required.

FIRST PRIZE WINNING SOLUTION CONTEST PROBLEM

1934

STUDENT CHAPTERS
AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

on

THE PROPOSED INSTALLATION OF FILTER PRESSES

ROBERT V. LUKES
University of Illinois

SUMMARY AND RECOMMENDATIONS

The optimum size of each type of filter press has been taken as that which gives the minimum total annual cost. The results found are here tabulated:

Type of Press	Size of Single press Sq. ft.	Number of Presses	Operating cycle Hrs.	ANNUAL COSTS Fixed charges $/yr.	Filter cloth $/yr.	Cleaning and Reassembling $/yr.	Total $/yr.
Chamber....	900	3	61.71	1710	635	577.50	2922.50
Leaf........	900	1	14.46	2026	904	246.30	3176.30
Difference in annual costs......							$253.80

DISTRIBUTION OF TIME DURING OPERATING CYCLES IN HOURS

Type of Press	Filtration at constant rate	Filtration at constant press.	Washing	Cleaning and Reassembling	Total
Chamber..............	1.11	15.5	42.6	2.5	61.71
Leaf..................	1.11	7.34	5.26	0.75	14.46

The chamber presses would require 1½ inch distance frames. The cake thickness in the leaf press would be 0.543 inches.

The results indicate that the most economical installation would consist of three 900 sq. ft. chamber type presses with 1½ inch distance frames. The total annual cost of this installation would be

$253.80 less than the most economical installation of the leaf type of press.

TEST FILTRATION

37 gals. of slurry filtered in 7 hrs., 10 min.

18.5 gals. of filtrate at constant rate and remainder at constant pressure.

$$37 \text{ gals. of slurry yield } \frac{1}{12} \times 1 \times 1 = \frac{1}{12} \text{ cu. ft. of cake}$$

$$\frac{1}{12} \text{ cu. ft.} = \frac{7.48}{12} \text{ gal.} = 0.623 \text{ gal. of cake.}$$

Therefore there are:

0.01684 gal. of cake per gal. of slurry
or 0.9832 gal. of filtrate per gal. of slurry;

$$37 - 0.623 = 36.377 \text{ gal. of filtrate during the test.}$$

The total press area was 2 sq. ft.; therefore the total volume of filtrate is 18.19 gal. per sq. ft. of press area and the total volume of filtrate at the end of the constant rate period is:

$$\frac{18.5}{2} = 9.25 \text{ gal. per sq. ft. of press area.}$$

The differential equation for a homogeneous compressible sludge is:

$$\frac{dV}{d\theta} = \frac{P^{1-s}A^2}{r'vV} \text{; which can be written in the form}$$

$$\frac{d\left(\frac{V}{A}\right)}{d\theta} = \frac{P^{1-s}}{r'v\left(\frac{V}{A}\right)} \text{; where } \frac{V}{A} \text{ is the total vol. of filtrate in gal.}$$

coming out of the press in time θ.

Integrating the above equation:

$$\int_0^{\theta} d\theta = \int \left[\frac{r'v}{P^{1-s}}\left(\frac{V}{A}\right) d\left(\frac{V}{A}\right)\right] + C = \theta_1 + \theta_2$$

Where

θ is the time, in hrs., up to the end of the filtration
θ_1 is the length of time of the const. rate period
θ_2 is the length of time of the const. pressure period.

For constant rate:

$$\frac{V}{A\theta} = \frac{P^{1-s}}{r'v\left(\frac{V}{A}\right)} = \text{constant}$$

$$\theta = \int_0^{9.25} \frac{1}{\left(\frac{V}{A\theta}\right)} d\left(\frac{V}{A}\right) + \frac{r'v}{P^{1-s}} \int_{9.25}^{18.19} \frac{V}{A} d\left(\frac{V}{A}\right)$$

$$\theta = r'v \left[\frac{\left(\frac{V}{A}\right)}{P^{1-s}}\right]^{*} \int_0^{9.25} d\left(\frac{V}{A}\right) + \frac{r'v}{P^{1-s}} \int_{9.25}^{18.19} \left(\frac{V}{A}\right) d\left(\frac{V}{A}\right)$$

$$\theta = r'v \frac{9.25}{(60)^{0.9}} \times \frac{V}{A}\Bigg]_0^{9.25} + \tfrac{1}{2} \frac{r'v}{60^{0.9}} \left(\frac{V}{A}\right)^2 \Bigg]_{9.25}^{18.19}$$

$$\theta = r'v \frac{(9.25)^2}{(60)^{0.9}} + \frac{1}{2} \times \frac{r'v}{60^{0.9}} \times (18.19^2 - 9.25^2)$$

$$\theta = 2.147r'v + 3.077r'v = \theta_1 + \theta_2$$

But $\theta = 7.1667$ hrs.

Therefore:

$$5.224r'v = 7.1667$$
$$r'v = 1.372$$

Therefore $\theta_1 = 2.147 \times 1.372 = 2.945$ hrs.
and $\theta_2 = 3.077 \times 1.372 = 4.222$ hrs.

* Simultaneous values of P and $\frac{V}{A}$ must be substituted here in order to evaluate the const. rate.