The distribution of the time during the operating cycle is as follows:

Constant rate filtration	1.11 hrs.
Constant pressure filtration	7.34 "
Washing	5.26 "
Cleaning and reassembling	0.75 "
Total time of cycle	14.46 hrs.

CONCLUSIONS

The optimum installation of chamber presses was found to be three presses of 900 sq. ft. area each. The annual cost of the filtration using the chamber presses would be $2922.50.

The optimum installation of leaf presses was found to be a single leaf press of 900 sq. ft. area. The annual cost of the filtration using the leaf press would be $3176.30.

The difference in annual costs of the two installations was found to be $253.80 which is approximately 8.5% of the annual cost of the filtration. Therefore on the basis of the annual cost of the filtration the most economical installation would be that of the three 900 sq. ft. chamber type presses using 1½ inch distance frames.

A.I.Ch.E. ANNUAL STUDENT COMPETITION—1935.

FOREWORD

A problem in the commercial recovery of acetone was submitted to the members of the student chapters of the American Institute of Chemical Engineers for solution in the Fourth Annual Problem Contest sponsored by the Institute. The contest was directed by the Committee on Student Chapters of which Dr. A. McLaren White of the University of North Carolina is Chairman. Mr. Thomas H. Chilton of the Experimental Station, E. I. duPont de Nemours and Company, Wilmington, Delaware, acted as chairman and Messrs. H. W. Jones and David T. Shaw of the Atlantic Refining Company, Philadelphia, as members of a sub-committee on awards.

The problem was an extremely practical one calling not only for the application of chemistry, chemical engineering, and machine design, but also for a knowledge of plant economics and accounting.

Three hundred and ninety-three students in thirty-four chapters attempted a solution of the problem. One hundred eighty-five solutions were submitted to the individual counsellors in final form. Forty-six were forwarded to the final judges. Rules of the contest limit the number of solutions from each chapter to three.

Burwell Spurlock of the University of Colorado was the recipient of the first prize of $100.00 awarded by Council on the recommendation of the committee on awards. Roland Voorhees of Princeton University received the second prize of $50.00, and Edward A. Belmore of the University of Virginia, third prize of $25.00. In recognition of honorable mention awarded Allyn A. MacPhail of the University of Colorado and J. A. Crowley of Yale University, the Institute presented copies of "Twenty-five Years of Chemical Engineering Progress in America."

Mr. Spurlock's first prize solution is published on the following pages, in accord with our regular custom.

FREDERIC J. LEMAISTRE,
Secretary

CONTEST PROBLEM

1935

NATIONAL STUDENT COMPETITION SPONSORED BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS UNDER THE DIRECTION OF THE COMMITTEE ON STUDENT CHAPTERS

(Open to Those Not Holding a Degree in Chemical Engineering)

Statement

Before undertaking the manufacture of a certain product, a chemical concern wishes to make an estimate of the probable losses in handling a solvent which must be evaporated into air in drying the product, and of the approximate investment which it is economically justified in making in a solvent recovery system. The engineer in charge of development has been requested to furnish a comparison of the costs of recovering the solvent by various methods. He has turned over to his assistants the calculations involved in the several methods under consideration, and the problem which you may consider as assigned to you is concerned with recovery by water scrubbing.

For the sake of simplicity, the solvent will be considered as acetone. It is to be removed from air by scrubbing with fresh water in a packed tower, and the solution is then to be distilled continuously in a plate column to reconcentrate the acetone to a strength of 99 per cent by weight. It is desirable to work below the lower explosive limit of acetone in the air, and enough air will be used so that the average composition entering the solvent recovery system is 1.50 per cent by volume. The amount of (100 per cent) acetone carried by the air to the solvent recovery system is to be 600 pounds per hour, and the operation will be carried on continuously, 24 hours per day, 350 days per year. The value of acetone will be taken as 10¢ per pound. The investment in solvent recovery equipment is to be charged off at the rate of 25 per cent per year. No operating labor or supervision is to be charged against the process, since it is considered that it can be handled by the men already engaged in other parts of the process. Likewise no cost for buildings to house the equipment need be estimated since it is considered that these are already available. Power will be charged at 1.0¢ per kw. hr., and the overall efficiency of motor and air fan (already available) will be taken as 70 per cent, independent of load. Steam will be charged at 30¢ per 1000 lbs. (97 per cent quality at 25 lbs. per sq. in. gauge pressure). Treated water (for

the absorption tower) will be charged at 2¢ per 1000 gallons, and cooling water for condensers at 0.5¢.

It is required to estimate the economical amount of water to use in the scrubbing tower, and the resulting concentration of the feed to the distillation system. The recovery of acetone in the scrubbing tower is to be taken as 99.75 per cent. It is assumed that this tower will operate at 25.0° C.; and that the heat of condensation of the acetone will be compensated for by the evaporation of water, so that the temperature may be considered constant throughout. Up to $x = 0.02$ mole fraction acetone in water, the equilibrium partial pressure of acetone out of the solution at 25° C. in atmospheres, p^*, may be taken as $p^* = 1.75x$ (Beare, McVicar and Ferguson, J. Phys. Chem. *34*, 1310-18 (1930)).

It is required to estimate the diameter and depth of packing in the absorption tower and the total costs of operation, including the loss of acetone. The mass velocity of the air leaving the scrubbing tower will be taken as 800 lbs./(hr.)(sq. ft. of gross tower cross-section). It is believed from tests already made on the packing selected, that the absorption coefficient at this air velocity will vary with liquor rate as follows:

$$Ka = 23\sqrt{W}$$

Where Ka = lbs. acetone absorbed per hr. per cu. ft. of packed volume per atmosphere.

W = lbs. of water per hr. per sq. ft. of tower cross-section.

The pressure drop at this gas velocity will be taken as 0.5" of water per foot of packing, independent of the water rate. The cost of the column, including foundations and erection, can be estimated at $15.00 per cu. ft. of packed volume.

It is required also to estimate the diameter of the column to be used for rectification of the recovered acetone solution, and the necessary number of plates. The reflux ratio in the concentrating section can be taken as 1.25 times the theoretical minimum reflux ratio, defined as moles of overflow per mole of distillate.

The fraction of the acetone going to the recovery system that it is allowed to waste in the liquor running from the still is 0.5 per cent. The superficial vapor velocity in the column, u, in feet per second, will be limited by the relationship $u\sqrt{\rho} = 0.5$, where ρ = vapor density, in lbs. per cu. ft. The distillation will be conducted at atmospheric pressure. The plate efficiency will be taken as 75 per cent, constant throughout the column; it will be defined as the number of theoretical plates required divided by the number of actual plates supplied. The plates, however, are made up in sections of two each, so that the number of plates both above and below the feed plate must be even (divisible by 2). The cost of the column, including foundations and erection, will be taken as $15.00 per plate per sq. ft. of column cross-section; but columns are available only in diameters which are multiples of 3". Heat will be supplied to the column by means of a closed steam coil, the cost of which may be taken as $2.00 per sq. ft. of heat transfer surface, and the overall heat transfer coefficient may be taken as 100 P.c.u./(hr.)(sq. ft.)(° C.). The feed is to be pre-heated to within 5° C. of its boiling point by heat exchange with the liquors leaving the still. The cost of this exchanger may be taken as $3.00 per sq. ft. of heat transfer surface and the overall heat transfer coefficient may be taken as 100. In estimating the cost of condensing water, it will be assumed that it is available at 25° C. and rises to 40° C. on passing through the condenser. The reflux will be returned at its boiling point, and the product will be cooled separately. (This cooler need not be estimated.) The heat transfer coefficient and the cost per sq. ft. of heat transfer surface for the condenser may be taken as the same as for the heat exchanger. Vapor-liquid equilibrium data for acetone-water at the atmospheric pressure boiling point are given in Table I.

You are to furnish the engineer in charge of development with calculations given in sufficient detail to permit checking of all figures required in estimating the cost of the recovery system for the most economic strength of feed to the rectifying column.

You are also to furnish a summary for the development engineer to transmit, including the costs of all items entering into the solvent recovery system, as follows:

- Value of acetone lost per year, separately, in air from absorption column and water from still.
- Annual cost of services, itemized; steam, filtered water, raw water, electric current.
- Total annual costs (except fixed charges).
- Investment required; detailed as to: absorption column, distillation column, heat exchanger, condenser, boiler.
- Total investment.
- Total annual costs, including fixed charges at 25 per cent.

Method of Presentation

The solution of this problem should be presented as a report which will give a summary of the investment cost and operating charges for the most economical solvent recovery system, accompanied by sufficiently detailed calculations to permit checking. In grading the reports, consideration will be given to the form of presentation, and to the judgment exhibited in selecting a method of attack, as well as to the accuracy of the assumptions and computations. All assumptions made should be clearly indicated.

Assume that the cost figures are intended eventually for the information of an executive who has had technical training, but is not familiar with modern chemical engineering developments. This executive will require that the engineer in charge of development 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.

The exact arrangement of the report as to form and content are left to the contestant's judgment of how he can best meet the above requirements.

It is to be assumed that the statement of the problem contains all the data available and your instructor is not to be consulted in regard to doubtful points. The problem is not to be discussed with any person whatever, although the use of textbooks, handbooks, journal articles, and lecture notes is allowable. Submittal of a report for the competition implies adherence to the above conditions.

Solutions must be received by local Chapter Counsellor fourteen days after statements of problems are issued at that chapter.

Each solution should be accompanied by a letter of transmittal giving only the contestant's name, school address, home address, and student chapter. This letter will be retained for identification by the Chairman of the Committee on Student Chapters. The solution itself must contain no reference to the student's name or institution by which it might be identified. Each Counsellor should select the best solutions from his chapter, not more than three in number, and mail these to A. McLaren White, University of North Carolina, Chapel Hill, North Carolina, to arrive not later than March 1, 1935.

TABLE I. VAPOR COMPOSITION FROM BOILING MIXTURES OF ACETONE AND WATER AT 1 ATM. (BERGSTRÖM, QUOTED BY HAUSBRAND)

Boiling Point	*Mole % Acetone in Liquid*	*Mole % Acetone in Vapor*
56.9° C.	100.0	100.0
57.1	96.84	98.41
57.3	93.84	96.85
57.5	90.94	95.32
57.8	85.5	92.36
58.6	73.60	88.9
59.4	63.75	87.3
60.0	55.40	86.3
61.4	42.00	84.6
62.5	31.75	83.0
63.7	23.75	81.2
65.2	17.1	79.3
68.2	11.7	75.8
73.5	7.2	68.6
77.5	5.2	62.3
83.0	3.33	52.8
90.0	1.61	34.0
93.0	0.95	21.6
95.0	0.63	14.8
98.0	0.313	7.35

FIRST PRIZE WINNING SOLUTION CONTEST PROBLEM

1935

STUDENT CHAPTERS
AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

By

BURWELL SPURLOCK
University of Colorado

Awarded 1st Prize, for excellence of summary and of graph of costs, and flow sheet, and for brevity of presentation. Points which were criticized included the following. The graph of costs might be improved by plotting annual instead of total investment charges so that all figures could be added to give total annual costs. Some consistency should have been maintained in the number of significant figures kept in the calculations,—a product of figures with three significant figures is carried out (p. 579) to give seven figures. This was one of a very few solutions which counted the feed plate separate (it was not intended to be so counted).—SUB COMMITTEE ON AWARDS.

Subject: Estimate of costs for construction and operation of a solvent recovery system.

Assignment: To obtain a summary of the investment cost and operating charges for the most economical system employing water scrubbing for the recovery of acetone.

Specifications

(a) Air-acetone mixture entering the system is 1.5 per cent acetone by volume.
(b) 600 lbs. of pure acetone enter the system per hour.
(c) Acetone is to be reconcentrated to 99 per cent by weight.
(d) Operation will be continuous, 24 hours per day, 350 days per year.
(e) Investment is to be charged off at the rate of 25 per cent per year.
(f) No operating labor or housing space need be considered.
(g) Allowable losses are 0.25 per cent in absorption tower and 0.50 per cent in column waste.