A.I.Ch.E. ANNUAL STUDENT CONTEST PROBLEM—1938

The problem and the prize winning solution are given on the foregoing pages, 429-487.

Council sponsors these contests annually through its Committee on Student Chapters. A sub-committee is appointed by the Committee on Student Chapters to handle the problem in its entirety. This committee for 1938 consisted of Dr. K. M. Watson, Chairman; Dr. G. B. Murphy, both of the Universal Oil Products Company, and Dr. G. G. Lamb of the Standard Oil Company of Indiana.

The sub-committee reported that in response to requests from educators and men in industry they attempted to make the problem as comprehensive as possible and less academic in type than those customarily encountered in textbooks. It will be noted from the statement of the problem on page 429 that these conditions were met perfectly.

Perhaps because of the nature of the problem, only a limited number of solutions were submitted. Twelve student chapters participated and submitted eighteen solutions. The successful contestants were the following:

1. Robert Egbert, Cooper Union, First Prize, $100.00.
2. John V. Hardy, Princeton University, Second Prize, $50.00.
3. Charles B. Miller, Cooper Union, Third Prize, $25.00.
4. Luther C. Peery, Virginia Polytechnic Institute, Fourth Prize, $10.00.
5. Donald C. Graham, Clarkson School of Technology, Fifth Prize, $10.00.
6. Herbert F. Weigandt, Purdue University, Sixth Prize, $10.00.

The solution submitted by Robert Egbert which received the first prize is printed in its entirety on pages 435-487.

Stephen L. Tyler
Executive Secretary

1939 ANNUAL STUDENT CONTEST PROBLEM

Each year the Council of the American Institute of Chemical Engineers authorizes the Committee on Student Chapters through a sub-committee to prepare a contest problem. All members of student chapters of the Institute are eligible to compete.

The sub-committee handling the 1939 Contest consisted of the following: J. H. Boyd, Jr., T. B. Drew, Hood Worthington, and R. P. Genereaux.

The attempt on the part of the committee is always to make the Problem one of a practical nature and typical of those which would be encountered in regular industrial work rather than to submit simply a problem of an academic nature.

The interest in this Contest was nation-wide and many very excellent solutions were submitted. The prize winners were as follows:

The first prize, the A. McLaren White Award of $100.00 was given to Mr. John F. Pelton, University of Tennessee. His solution along with the Problem appears on the following pages.

The second prize of $50.00 was awarded to Robert C. Holmes, University of Illinois, and the third prize of $25.00 to Robert Herzog, Cooper Union.

Three further awards of $10.00 each are authorized but their granting is left to the discretion of the committee. Their opinion was that none of the remaining solutions submitted were sufficiently superior to the others to enable them to make a proper selection.

CONTEST PROBLEM

1939

Student Chapters—American Institute of Chemical Engineers

Open Only to Undergraduates or Those Without a Degree in Chemical Engineering

To the Contestant:

This is nearly a real problem. It is presented, as far as is practicable, in the way it would reach you if you were a new junior engineer in the Design Division of our Company. You are John H. Jones. The first letter below is a memorandum from your superior, Mr. Genereaux, giving you assignment and instructions. The rest of the letters (except that indicated as having been attached to the original memorandum) are in response to your notes or telephone calls requesting information from available sources within the Company.

We know there is an answer: we have done the problem with the information given you—and, moreover, the plant which is its prototype (it doesn't really handle Cl_2) actually works and its construction checks the right answer.

The Committee

Rules of the Contest

Solutions will be graded on (a) conclusions reached, (b) accuracy of computations and (c) form of presentation.

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 until after March 15, 1939. This is particularly important in cases where neighboring institutions may not begin the problem until after its completion by another chapter. The use of textbooks, handbooks, journal articles, and lecture notes is permitted. Submittal of a solution for the competition implies adherence to the above conditions.

A period of not more than 21 consecutive days is allowed for completion of the solution. This period may be selected at the discretion of the individual counsellor, but a solution must be postmarked not later than midnight March 15, 1939, in order to be eligible. Each solution should be accompanied by a letter of transmittal giving only the contestant's name, school address, home address, and student chapter, lightly attached to the report. This letter will be retained for identification by the Chairman of the Committee on Student Chapters. The solution itself must bear no reference to the student's name or institution by which it might be identified. Each counsellor should select the best solution, or solutions, from his chapter, not to exceed two in number, and send these registered mail to Professor Joseph C. Elgin, Princeton University, Princeton, New Jersey.

* * * * * * * *

Engineering Department

December 1, 1938

Memorandum to Mr. J. H. Jones

From R. P. Genereaux

Project 1234—Chlorine Condensers, B-Factory

In confirmation of my oral instructions of this morning, please prepare information for estimating purposes and write the Appropriation Request for the above project. To enable the Estimating Division to prepare the estimate, it will be necessary for you to send them with a covering letter an arrangement sketch of the proposed installation with equipment and piping sizes indicated. All the necessary instruments and controls and notes on their operation should be included on the sketch or on an accompanying sheet. Appropriation Requests at this stage include the headings: "Present Status," "Proposed Installation," and "Method of Operation." You understand this form should be brief, since when completed with the estimate it will be submitted to the executives for authorization. All of your calculations should be grouped and indexed for filing in the project file.

The project calls for the installation of twelve chlorine condensers and a refrigeration system. Preliminary study has indicated the suitability of a refrigeration system in which liquid "Freon-11," supplied from a flash evaporator, is circulated with centrifugal pumps through the shell side of baffled chlorine condensers, and is returned in the liquid state to the flash evaporator which operates at the pressure corresponding to the refrigerant supply temperature. A portion of the return liquid flashes and goes to a compressor and condenser from which it returns to the flash evaporator. The liquid level in the flash evaporator must remain between certain levels at all times to insure sufficient head on the pumps and prevent liquid from entering the compressor. The circulating system should be so arranged that sudden variations in the number of condensers on the line will be automatically cared for.

There are available for use on this project twelve heat exchangers now in excess machinery. The specifications are attached. You might ask Mr. T. B. Drew to help you determine whether or not they will be suitable. They are of the type shown in Fig. 87 of Badger & McCabe, p. 166, 2nd Edition. The 2" nozzles could be replaced if they are undesirable.

Attached hereto is a letter from the plant, together with a sketch showing the equipment which you are to specify. You will need operating and investment cost data on refrigeration equipment and pumps. I believe Mr. J. C. Lawrence has some data on other installations. The attached table gives installed costs of standard steel pipe and cork insulation of "special brine" thickness, obtained from the Estimating Division in connection with a recent project. Mr. H. Worthington will assist you on engineering properties of the fluids involved.

Our power cost is usually figured at $0.008/kw. hr. and the amortization rate at 10% per year. The above information should enable you to fix the optimum refrigerant supply temperature. Heat picked up in the circulating lines can be neglected in estimating the refrigeration load. Please express all temperatures in °C. Do not fail to provide safety items and indicate the procedure in starting up, operating, and shutting down the refrigeration system.

Specifications of Existing Exchangers

Type: Shell and Tube—Single pass each side.

Bundle:

No. tubes:	50	Metal: Steel
Tube size:	1" O.D.	Gage: #10 B.W.G. (0.134" thickness)

Tube length:	10 ft. between tube sheets
Tube spacing:	1⅜" on centers
Tube arrangement:	Equilateral triangle
Cross Baffles:	Segmental type
Altitude of open segment:	1/3 shell diam.
No.:	37, equally spaced; 6" from tube sheet to first baffle
Thickness:	#10 B.W.G. Metal: Steel

Longitudinal Baffles: None, but longitudinal side strips are provided to prevent by-passing through clearance between bundle and shell.

Shell Diameter:	14" I.D. Metal: Steel
Tube Sheet Thickness:	1½" Metal: Steel
Nozzles on Shell:	4" Std. pipe size
Nozzles on Heads:	2" Std. pipe size

Pipe and Insulation Costs

Diameter, inches	Pipe, $/ft.	Insulation $/ft.
1	0.20	1.08
2	0.33	1.34
4	0.95	2.23
6	1.57	3.19
8	2.69	5.79
10	4.52	6.38
12	5.62	7.00
14	6.08	7.71
16	6.96	8.21
18	7.76	9.19
20	8.64	9.97

* * * * * * * *

Production Department

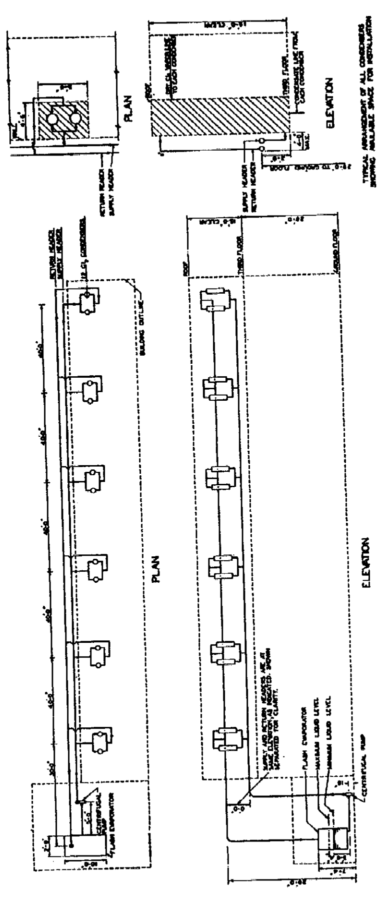
B-Factory

November 30, 1938

Mr. R. P. Genereaux
Design Division
Engineering Department

Project 1234—Chlorine Condensers, B-Factory

In accordance with our recent conference and your suggestion of a circulating liquid "Freon-11" refrigeration system for condensing



chlorine, we are sending herewith a sketch indicating space limitations and the most convenient locations for the condensers in the present building. Please note that the supply and return headers would be located most conveniently as shown because this is practically the only place where a straight run of pipe for the full length of the building is possible.

The plant has a total capacity of 16,000 lb./hr. of chlorine from a battery of twelve essentially identical units. The chlorine will be fed to the proposed condensers at room temperature and two atmospheres absolute pressure. Any number of units may be in operation at a given time, depending on our current production schedule and on shutdowns due to mechanical failure. Past experience indicates that we operate 24 hrs. per day approximately 75% of the year.

We suggest the pressure of the "Freon-11" in the circulating system be kept above atmospheric where it is at all possible, so that leaks may be readily detected.

Production Department
J. H. Boyd, Jr., Manager B-Factory

* * * * * * * *

Engineering Department

December 2, 1938

Mr. R. P. Genereaux
Design Division
Attention of Mr. John H. Jones

Project 1234—Chlorine Condensers, B-Factory

Physical Properties of Chlorine and "Freon-11"

Chlorine. With the exception of the thermal conductivity, values of the physical properties of chlorine necessary for condenser calculations are given in or can be derived from related data from the International Critical Tables, and we consider these values to be satisfactory. For the thermal conductivity of liquid Cl_2, an estimate is 0.20 P.c.u./(hr.) (sq. ft.) (°C./ft.). Your attention is called to a discrepancy between the I.C.T. values for the latent heat and that given by Perry. The I.C.T. vapor pressure and specific volume data indicate $\lambda = 61\text{-}62$ P.c.u./lb. at your condensation temperature, and are consistent with the I.C.T. value of λ given for the normal boiling point. We suspect a typographical error in Perry's table.

"Freon-11." The attached table, furnished by the manufacturer, gives all the essential physical properties.

TECHNICAL DIVISION
HOOD WORTHINGTON

PHYSICAL PROPERTIES OF LIQUID "FREON-11"

Temp. ° F.	Abs. Pressure lb./sq.in.	Density lb./cu.ft.	Heat of Liquid from —40° F. B.t.u./lb.	Viscosity Centipoises
—40	0.7391	101.25	0.00	0.980
—36	0.8471	100.96	0.79	—
—32	0.9682	100.66	1.58	—
—28	1.103	100.37	2.36	—
—24	1.253	100.07	3.15	—
—20	1.420	99.77	3.94	0.801
—16	1.605	99.48	4.73	—
—12	1.810	99.18	5.52	—
— 8	2.035	98.87	6.31	—
— 4	2.283	98.57	7.10	—
0	2.555	98.27	7.89	0.677
10	3.352	97.50	9.88	—
20	4.342	96.72	11.87	0.586
30	5.557	95.94	13.88	—
40	7.032	95.14	15.89	0.517
50	8.804	94.34	17.92	—
60	10.90	93.53	19.96	0.461
70	13.40	92.71	22.02	—
80	16.31	91.88	24.09	0.417
90	19.69	91.04	26.18	—
100	23.60	90.19	28.27	0.380

Probable value of thermal conductivity $k = 0.08$

* * * * * * * * *

ENGINEERING DEPARTMENT

December 2, 1938

MR. R. P. GENEREAUX
Design Division
Attention of MR. JOHN H. JONES

PROJECT 1234—CHLORINE CONDENSERS, B-FACTORY

UTILIZATION OF DISUSED STEEL HEAT EXCHANGERS

We find no good reason why the heat exchangers now in excess machinery cannot be converted into condensers with the chlorine

inside the tubes as you suggested over the telephone this morning. The Metallurgical Section reports that since the chlorine in this operation is almost perfectly dry, there is no expectation of serious corrosion of the steel tubes at the temperature of condensation. We understand that a slight contamination with iron is of no import at this point in the process.

An estimate of the pressure drop on the shell side of the exchangers can be made on the assumption that the principal resistance to flow through the tube bundle arises in the transverse flow across the bundle through the spaces between adjacent pairs of baffles. For any one such space the textbook method for flow across tube banks may be applied. If you refer to Walker, Lewis, McAdams, and Gilliland, ρ is missing from the Reynolds number of Equation 21, p. 96 (3rd Edition). For closely baffled bundles, the resultant approximation is usually fairly good, but if the pressure drop must be had very accurately, direct test data should be obtained.

In calculating the coefficient of heat transfer for the shell side, we use 60% of the value given by the formula for flow across tube banks. The deduction of 40% really is an allowance for by-passing of fluid through the clearances between the baffles and the shell and through the crevices around the tubes where the tubes pass through the baffles.

TECHNICAL DIVISION
THOMAS B. DREW

* * * * * * * *

ENGINEERING DEPARTMENT

December 5, 1938

MR. R. P. GENEREAUX

Design Division

Attention of MR. JOHN H. JONES

PROJECT 1234—CHLORINE CONDENSERS, B-FACTORY

The data you requested yesterday are taken from recent projects and may be summarized as follows:

For the tonnage you indicate, the refrigeration equipment installed cost and the power required are, for the temperatures indicated:

° C.	$/Ton	B.H.P./Ton
0	170	1.5
—20	240	2.4
—40	310	3.65

The cost of two sizes of centrifugal pumps for the service you require are:

G.P.M.	Pump	Motor, Etc.	Total	H.P.
550	$ 490	$ 650	1140	30
1100	$1185	$1250	2435	60

We suggest you interpolate and extrapolate these data for other capacities.

DESIGN DIVISION
J. C. LAWRENCE

A.I.Ch.E. Annual Student Competition

FIRST PRIZE WINNING SOLUTION

Contest Problem, 1939, Student Chapters, A.I.Ch.E.

BY JOHN F. PELTON, University of Tennessee Chapter
University of Tennessee, Knoxville, Tennessee

* * * * * * * *

ENGINEERING DEPARTMENT

January 24, 1939

Estimating Division

PROJECT 1234—CHLORINE CONDENSERS, B-FACTORY

Specifications for Estimate

Please prepare a complete estimate on the above project.

This project calls for the installation of twelve chlorine condensers and a refrigeration system. "Freon 11" from a flash evaporator, at a temperature of −29° C., is circulated with a centrifugal pump through the shell side of a baffled chlorine condenser, and is returned in the liquid state to the flash evaporator which operates at a pressure corresponding to the refrigerant supply temperature (1.6 lb./sq. in. absolute). A portion of the liquid flashes and goes to a compressor and condenser and is returned to the flash evaporator.

The refrigerant level in the flash evaporator is held within the specified limits by means of a float operated valve which regulates the return flow from the refrigerant condenser. The flow of refrigerant through the chlorine condensers is controlled by a diaphragm operated valve on the refrigerant inlet of each condenser. A relief valve on the refrigerant return line, just above the flash evaporator, maintains the pressure slightly above atmospheric at the highest point in the system, so that leaks may readily be detected.

Attached hereto is an arrangement sketch of the proposed installation and separate sheets giving equipment specifications, notes on the