American Institute of Chemical Engineers

STUDENT CONTEST PROBLEM

1962

345 East 47 Street • New York 17, New York

TO THE CONTESTANT

In the development of the Student Contest Problem for 1962 an attempt has been made to emphasize to the student, who is about to enter the chemical industry, the importance of the over-all economics of any practical industrial situation. The dollar sign and chemical engineering are inseparable. Frequently the chemical engineer is called on for preliminary designs for all or portions of a projected plant. Then in the final designing stages of a new process unit, following the initial economic-justification studies, he may be called upon to make optimization calculations to determine which of many process variables will produce the desired product most economically. At other times he may be called upon to evaluate a process proposal offered by an outside engineering firm. Still another type of problem is frequently encountered, namely to combine two or more process designs, often filling in missing parts of the design and determining the over-all economic attractiveness of the entire manufacturing complex. As the number of operations in a study is increased, the over-all economic balance becomes more complex. Furthermore, management frequently asks for these studies on short notice, and the engineer often needs considerable experience in processing and economics to enable him to determine quickly the major divisions of the problem and the aspects which are most important to the economics.

Because of time limitations on the contestant, the following problem has been simplified by considering only a few of the variables that such a study would require and by making certain simplifying assumptions. Therefore, although many of the data are exact, all data furnished should be considered for use in connection with this problem only and are not necessarily accurate.

For the solution of the problem the student will be C. E. Newblood, Junior Process Engineer in the Engineering Department of the Petroleum Products Unlimited Company. His immediate supervisor is V. J. Minor, Senior Engineer, who reports to R. W. Oldshue, Project Evaluations Supervisor. All other staff members will be identified as presented.

An attempt has been made through the use of conference notes and interdepartmental memoranda to present the problem in a manner typical of what the new engineer will encounter in industry. Although the policies of individual companies will vary, this method is widely used, and it should emphasize to the student that in industry seldom is a study the responsibility of one man, because the evaluation engineer requires a variety of information in order to do his job.

A very important part of such an assignment is the clear presentation of the results obtained, so that they may be easily and quickly understood by management. At the same time that a clear, concise summary is required, the report must also present in the supplemental discussion a detailed explanation of how the results were obtained. The factors that will be considered in judging the report are listed in the Appendix under Solutions Judging Check List.

PETROLEUM PRODUCTS UNLIMITED
COMPANY, OILVILLE, U.S.A.

INTERDIVISION MEMORANDUM 62-17

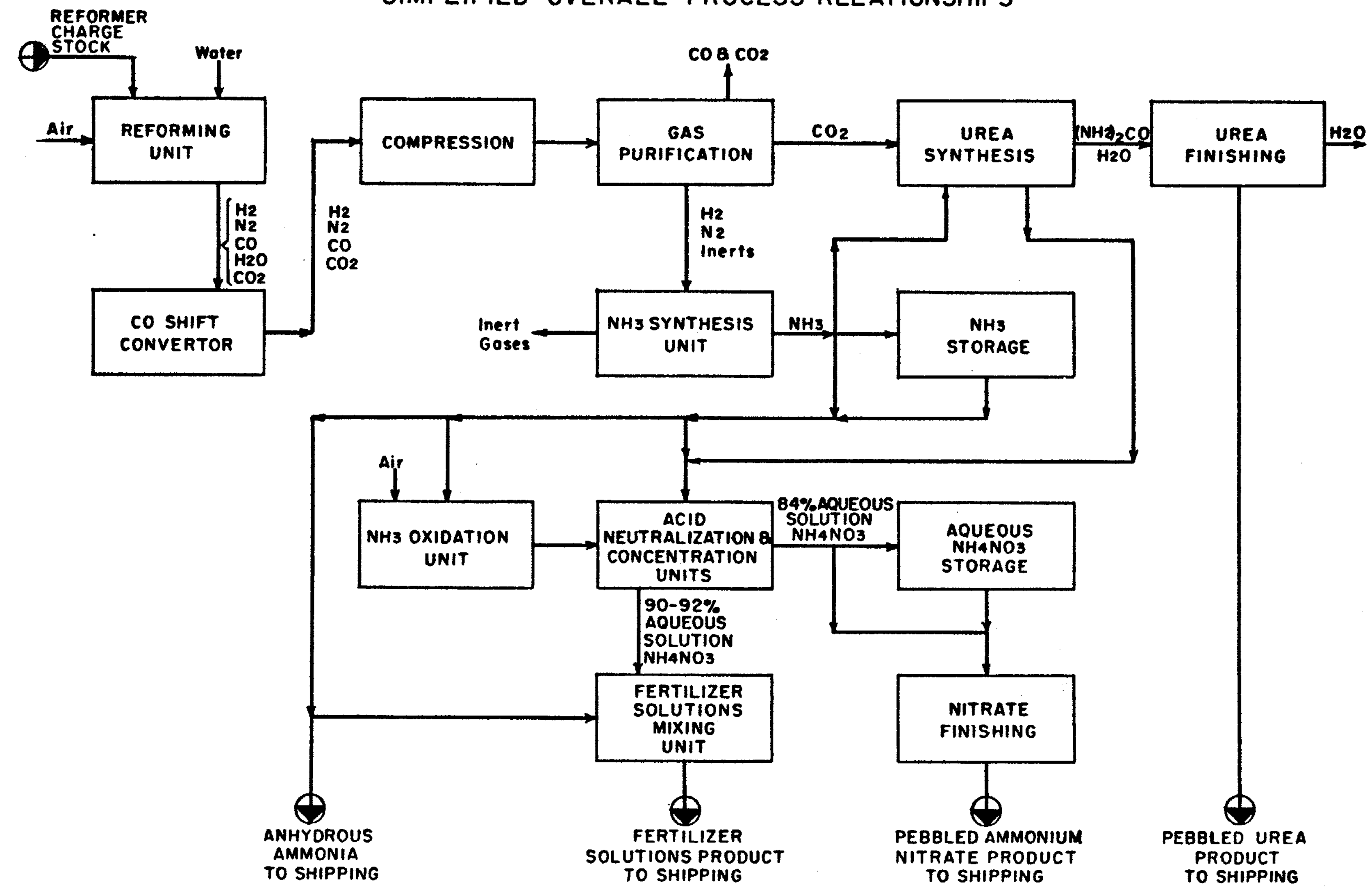
DATE: May 3, 1962
SUBJECT: Agricultural Chemicals Expansion

TO: R. W. Oldshue, Project Evaluations Supervisor
FROM: J. H. Major, Director of Engineering and Evaluation Services

cc: (1) D. R. Boyle, Physical Sciences Supervisor
(2) H. H. Seed, Agricultural Sales Research Manager
(3) I. M. Tight, Cost Control Supervisor
(4) E. K. Watts, Utilities Superintendent, Oilville Refinery

As you know, for some time we have been exploring the economics of various uses for the surplus hydrogen-rich off gases of the Oilville Refinery. Our studies are complete except for the study on agricultural products. It is my recollection that this study is awaiting a cost estimate on the fertilizer-solutions production facilities. Since the Development Committee would like to review this over-all program at its next meeting on May 16, please have one of your engineers prepare an evaluation based on the product distribution that H. H. Seed recommends. Please have a copy of the report on my desk on or before May 15 to give me time to look it over before the meeting. Since the report will be used directly by the Development Committee and, if recommended, even submitted directly to the Manufacturing Council, it is imperative that it be carefully written in accordance with our standards, with a brief letter of transmittal, addressed to Dr. B. B. Wilkins as Chairman of the Development Committee.

FIGURE I
SCHEMATIC FLOW SHEET
SIMPLIFIED OVERALL PROCESS RELATIONSHIPS



I realize that this is short notice and that you are handicapped by vacation schedules, particularly since V. J. Minor, who has handled the initial stages of this study, is on vacation. However I know you'll come through. Why don't you give that new chap, Newblood, a try at it? During the interviews he struck me as a right level-headed fellow.

By copy of this memorandum I am requesting that Boyle, Seed, Tight, and Watts cooperate with you, as usual, in furnishing any information they have that may be of help to you.

J. H. Major

JHM:vcu

CONFERENCE NOTES

May 4, 1962

Present: R. W. Oldshue, C. E. Newblood

Mr. Oldshue: Charlie, as you can see from Dr. Major's memorandum, we need to prepare an economic appraisal of a nitrogen products plant as a part of our broader study on the utilization of excess hydrogen-rich off gases. This appraisal has been pending for several weeks, and we have delayed completion to wait for cost estimates from a contractor on the fertilizer-solutions manufacturing facilities. Since these haven't come in, we shall have to make an estimate on this portion ourselves. I realize that you have been with us for only a short time. Ordinarily you would receive direct supervision from a more experienced engineer, but we are a little short-handed this month.

First, I will give you a brief over-all concept of the job and then we can discuss other details. To help you understand the relationships between the units, here is a schematic flowsheet (Figure 1) that I hurriedly sketched. I have not included any quantities of products or feedstock. You will have to develop the over-all material balance from the market projections, which Mr. Seed will furnish you, and from the individual efficiencies of the units, which I will give you. Briefly, the over-all process plan, as shown in Figure 1, is that either natural gas or hydrogen-rich gas is converted to ammonia. A portion of this ammonia is reacted with carbon dioxide rejected from the ammonia plant to give urea. Another portion of the ammonia is oxidized to produce nitric acid. Still another portion of the ammonia is reacted with the nitric acid intermediate to yield ammonium nitrate (AN). Some of the aqueous ammonium nitrate solution is dried and sold as a dry product; the remainder is mixed with ammonia and sold as a liquid mixture.

Now we have received estimates on the ammonia plant (Table 1) using both natural gas and hydrogen-rich gas. After you have determined what size the ammonia plant is to be, decide, on the basis of payout on investment before taxes, whether we want to use natural gas or the hydrogen-rich gas as feed to the reformers. I expect that you will find the latter to be more attractive.

Table 1. INVESTMENT AND OPERATING REQUIREMENTS FOR AMMONIA PLANTS

	Natural Gas	Hydrogen-rich Gas
MSCF/ton NH_3, consumed	21.7	83.8
Charge stock vol. %		
H_2		87.5
N_2	0.4	
O_2	0.1	
CH_4	94.2	6.3
CO_2	0.4	
C_2H_6	4.2	3.9
C_3H_8	0.7	2.2
C_4H_{10}		0.1
Total	100.0	100.0
Catalyst, lb./ton NH_3		
Reforming	0.22	
Shift	0.38	
Synthesis	0.11	0.11

Table 1. (Continued)

Chemicals, lb./ton NH_3

	Natural Gas	Hydrogen-rich Gas
MEA	0.56	
Copper	0.20	
Acetic acid	0.30	
Ammonia	0.20	
NaOH		2.0
Utilities		
Steam (220 lb./sq. in. gauge)/(lb.) ton NH_3	6,570	900
Cooling water (80 ° F.), gal./ton NH_3	99,000	64,000
Boiler feed water, gal./ton NH_3	187	
Electric power, kw.-hr./ton NH_3	50	19
Fuel gas, 1×10^6 B.t.u/ton NH_3	18	8.5
Erected plant cost		
Capacity, per stream day	Investment as of August, 1962 (ENR=854)	
60 tons	$2,400,000	$2,200,000
100 tons	$3,400,000	$3,100,000
150 tons	$4,500,000	$4,150,000

Courtesy of The M. W. Kellogg Company. Reprinted by permission.

Estimate storage costs separately. Do not interpolate for investment; use multiples of one of the above standard plant sizes. Allow 10 men/shift for natural-gas feed, 9 for hydrogen gas.

Mr. Newblood: Pardon me, will you please define payout and reformers These are two terms I'm not certain about.

Mr. Oldshue: Pardon me for forgetting that this type of work is new to you. Here is a list (Table 2) defining some of the terms we use here which you might find helpful.

Here too is some preliminary information on the Montecatini process for manufacturing urea (Table 3). In the absence of more detailed data you may use this. We shall be selling all the urea in a pebbled form in 80-lb. bags. Note that we contemplate using the once-through process and sending the unreacted ammonia to the ammonium nitrate manufacturing facilities, where it will furnish part of the ammonia necessary for reacting with nitric acid. This gaseous ammonia amounts to 25 tons of ammonia/100 tons of urea produced. Quite some time ago V. J. Minor prepared a study of nitric acid and ammonium nitrate plants. Here is a summary of his results (Table 4) that you may use in your analysis.

Unfortunately, we have not received any estimates on a fertilizer-solutions mixing unit; so you will have to make a preliminary design and cost estimate on this portion. Referring to this sketch (Figure 2) as a possible method for doing this, I suggest that you consider using a batch process. This solution is sold in 10,000-gal. tank cars. While one mixing tank of finished solution is being cooled, sampled, analyzed, and pumped to the loading station, the other tank can be recharged with the heel from the previous batch. Then ammonium nitrate solution and ammonia can be added while the mixture is circulating through the solutions cooler to remove the heat of mixing. Probably you will have to recirculate additional heel or finished solution from the tank (as shown by asterisk on Figure 2) to mix with incoming AN solution and ammonia to prevent flashing of ammonia from the mixer. Remember that the allowable pressure and corresponding temperature leaving the mixer are governed by pressure drop across the exchanger during mixing. The heel tank is provided so that, if we are producing a multiplicity of solutions, solution remaining after a rail car is loaded can be drained from the mixing tank to the heel tank to prevent contamination. Owing to pumping losses, etc., between ammonium nitrate production, storage, and the solution-mixing areas, the efficiency of utilization of ammonium nitrate is 99%. Owing to the vent losses during mixing, loading, sampling, and recharging, the loss of

Table 2 GLOSSARY OF TERMS

Ammonia = compound having the formula NH_3, produced by catalytically combining H_2 and N_2; feedstocks may be coke, coal, natural gas, a hydrogen-rich gas, light hydrocarbons, etc. Used in many industries, but major use is in fertilizers

Ammonium nitrate = inorganic water-soluble solid, NH_4NO_3, used in fertilizers and explosives; produced by reacting nitric acid and ammonia

ENR index = empirical measure of the cost of construction vs. time developed by the publishers of Engineering News Record; to convert cost of equipment or a plant from one date of construction to another date, multiply the first cost by the ratio of ENR index for the the dates involved. Use 875 as the current ENR index.

Heel = liquid remaining in a tank after it has been emptied of most of its contents; serves several purposes such as ensuring flooded pump suction, initiating next reaction mixture, solubilizing for a mixing process, etc.

Hydrogen-rich gas = gas of variable composition, usually 80% or more in H_2 content, obtained in various refining processes

Inhibitor = any of several chemical mixtures employed to supress or prevent some particular action. In this problem it refers to chemicals used to retard corrosion.

Manufacturing cost = actual cost involved in producing a finished product; including feedstock cost and all direct and indirect production expenses

Nitrogen fertilizer solution = any of several combinations of ammonia, ammonium nitrate, water, urea, and sodium nitrate used as fertilizers by direct application as a liquid or for a feedstock in solid mixed fertilizer manufacture

Operating factor = percentage of the total year that the plant is actually operating. Obtained by dividing stream days by 365

Payout period = estimate of the economic attractiveness of a project measured as the number of years required to recover the initial investment. Numerically it is equal to the investment divided by the sum of annual depreciation plus profit and may be expressed on either a before or after tax basis.

Pebbled = in this problem a free-flowing, spherical form of fertilizer solids

Reforming = process wherein saturated hydrocarbons are decomposed by steam according to the basic equation

$$C_nH_{(2n+2)} + n(H_2O) \longrightarrow n(CO) + (2n+1)\,H_2$$

Return = measure of the economic attractiveness of a project expressed as a rate of return in per cent on the required investment; numerically equal to 100 times the profit before interest charges divided by investment. It may be calculated on either a before or after tax basis.

Shift converter = unit for reacting the carbon monoxide contained in a reformer effluent with steam to form additional hydrogen and carbon dioxide

Urea = solid organic compound $(NH_2)_2CO$, formed from NH_3 and CO_2 by the following reactions:

$$2NH_3 + CO_2 \longrightarrow NH_2COONH_4$$

$$NH_2COONH_4 \longrightarrow NH_2CONH_2 + H_2O$$

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ammonia is also 1%. After you have designed this equipment, then estimate its cost according to the methods outlined by Mr. Tight. When you have finished, include a revised flowsheet showing equipment sizes and line sizes as an appendix to the report. I will detach this for our files. You might find the plot in Aries and Newton (1), page 79, for economic pip-diameter selection helpful. Please also show the arrangement of instruments and valves, including relief valves, that you consider necessary for this operation. Indicate any lines that require insulation or steam jacketing. Now any questions?

Mr. Newblood: Yes, sir. Will this mixing unit operate semicontinuously by alternating between tanks?

Mr. Oldshue: No. For safety in car loading, design it to operate semicontinuously during the 8 to 4 day shift only. Here are a few general suggestions to consider:

1. Add 20% excess capacity in pumps, exchanger, and scrubber to allow for uneven shipping schedules, the possibility of different solutions compositions, etc.
2. Use a 200 gal./min. loading rate to conform to our standard loading practice, and do not load above 100° F.
3. Assume 91 to 92 wt. % aqueous ammonium nitrate at 110° C., available at required rate from the AN concen-

trator and anhydrous liquid ammonia available at an average of 65° F.
4. Allow one-half hour for sampling and analysis of finished solution before loading. This may be done during final cooling to loading temperature after the mixing is complete.
5. Assume the sample recovery tank to be 200 gal. and the heel tank to be about 15% of the capacity of a mixing tank.
6. Do not use an approach of less than 15° F. in exchangers.
7. Assume premixed aqueous solution of corrosion inhibitor available from elsewhere in plant once daily. Specific gravity of solution is 1.34 at loading temperature, and 40 gal./10,000 gal. is added after mixing has been completed.
8. Assume that coefficients for the solutions side of exchanger during mixing are 80% of those for water at the same temperature and velocity.
9. You may use this chart (Figure 3) for estimating the thickness of the tanks. Use maximum working pressure plus either 10% or 20 lb./sq. in gauge, whichever is greater, as design pressure.
10. Provide spares for all pumps.
11. Assume 330 stream days/yr., all units except the solutions-mixing unit operating on 24-hr. basis.
12. Assume that all necessary product and intermediate storages are included in HNO_3, urea, and ammonium nitrate plant investments. No storage is required for fertilizer solutions which are loaded directly to tank cars. Provide 4 days storage for NH_3 in insulated spheres.

Table 3. INVESTMENT AND MATERIAL REQUIREMENTS FOR UREA PLANTS

Investment *(5)*
$21,000/ton/day (This is 1955 cost; multiply by ENR ratio to convert to present cost. 1955 average ENR = 660.)

Utilities Requirement *(6)* per ton pebbled product

Electricity	165 kw.-hr.
Steam	4,100 lb.
Cooling water	18,200 gal.

Feedstock Requirements *(5)*
NH_3, gross feed 0.83 ton/ton
CO_2, gross feed 0.89 ton/ton
(Assume CO_2 available as required from NH_3 plant and cost of recovery included in other urea and NH_3 processing costs.)

Labor 5 men/shift

Table 4. INVESTMENT AND OPERATING REQUIREMENTS FOR HNO_3 AND NH_4NO_3 PLANTS

COMPOUND	HNO *		AN production†		AN finishing‡	
INVESTMENT	Capacity	$	Capacity	$	Capacity	$
(Current costs)	125	1,710,000	200	322,000	150	1,900,000
	250	2,600,000	400	505,000	250	2,625,000
			600	710,000		
Utilities and chemicals, per ton of capacity						
Steam, lb.	-2,000 (credit)		250		190	
Electricity, kw.-hr.	327		2.1		6	
Cooling water, gal.	28,000		50		20	
Platinum catalyst, troy oz.	0.0075					
Coating material					4 wt. % of finished product	
Raw materials, efficiency % of theory						
NH_3	93		98			
HNO_3			99			
NH_4NO_3					100‡	
Labor Requirements, men/shift	1		2		7 dayshift only 4 remainder	

*Rated in tons 100% acid/stream day, produced as 57% (wt.) aqueous solution.
†Rated in tons 100% AN/stream day, produced as 90-92% (wt.) aqueous solution.
‡Coating addition equals handling loss. Rated in tons finished product/stream day.

FIGURE 2
PROPOSED FLOW DIAGRAM
FOR
MANUFACTURE OF NITROGEN FERTILIZER SOLUTIONS

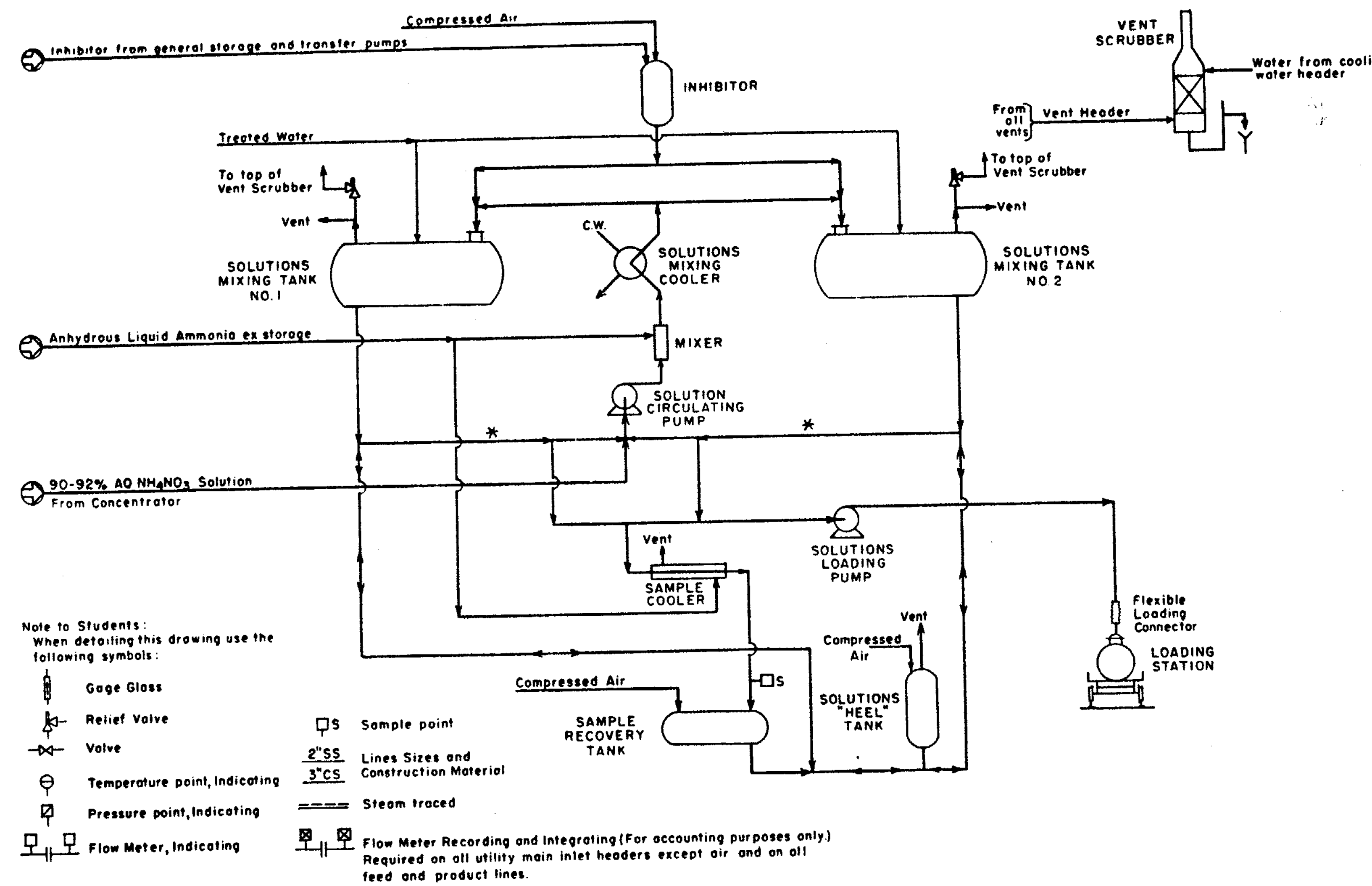


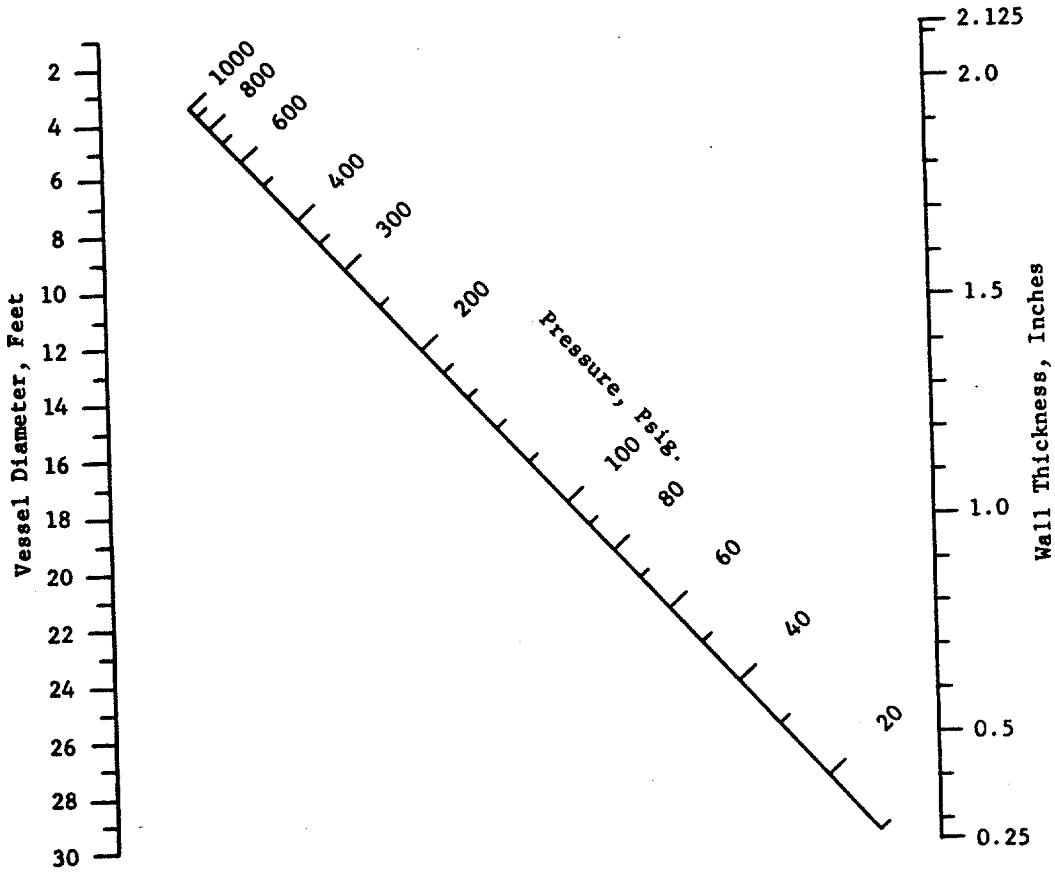
Figure 3

REQUIRED WALL THICKNESS FOR PRESSURE VESSELS

Includes 0.125 Inch Corrosion Allowance

Based on equation:

$$t = \frac{12PD}{2(0.85)(55{,}000)/4 - 1.2P} + 0.125$$



NOTE:

Minimum thickness
D < 5' 1/4"
5' < D < 15' 3/8"
Take no credit for lining or alloy cladding strength. With alloy eliminate 1/8" corrosion allowance.

Please attach your calculations to your report, Charlie. I will remove them and have V. J. Minor review them when he returns.

INTERDIVISION MEMORANDUM 62-18

DATE: May 4, 1962
SUBJECT: Estimating Methods and Costs—Oilville Refinery

TO: C. E. Newblood, Junior Process Engineer
FROM: I. M. Tight, Cost Control Supervisor

As Dr. Major requested, I am forwarding some cost information which you may find useful. Table 5 and Figures 4 and 5 give equipment costs either f.o.b. or installed at an ENR index of 700. If you have need for any equipment costs that I have not listed, you may refer to Aries and

Table 5. EQUIPMENT COSTS
ENR 700

Centrifugal pumps

Gal./min.	Max. head, ft. of water	Cast iron* cost, $f.o.b.	Alloy const. chemical type† cost, $f.o.b.
100	50	450	500
100	100	550	650
300	50	600	700
300	100	650	830
1,000	50	700	950
1,000	100	800	1,100
3,000	50	1,000	1,250
3,000	100	1,300	1,600

Electric motors

Hp.	Cost, $f.o.b.
5	250
10	400
15	500
25	750
40	1,200
100	2,950

Storage spheres

45 lb./sq. in. gauge working pressure - erected cost $\$ = 36{,}600(C)^{0.57}$ where C = capacity in thousands of 42-gal. barrels.

Standard sample coolers

Alloy - double pipe type f.o.b. $200 (Ignore alloy-carbon increment.)

Atmospheric vent scrubbers
(Including 15 ft. of 1-in. packing rings and stack)

Diameter, in.	Cost, $f.o.b.
12	900
16	1,050
20	1,200

Loading stations

To serve double track - complete with 10 hp. capstan type of car puller and weigh scales $45,000 erected (Type B cost in Table 8)

In line mixers

Mixing rate lb. NH_3/hr.	f.o.b. $ alloy‡
10,000	2,000
20,000	3,000
30,000	4,600

*C. I. casing, alloy sleeves, max. press. 250 lb./sq. in. gauge, temp. 250°F.
†18-8, Worthite etc., max. press. 250 lb./sq. in. gauge, temp. 300°F.
‡C. steel is 1/3 of this, for allocation of A and C types of equipment costs.

Figure 4

COST OF CARBON STEEL DRUMS

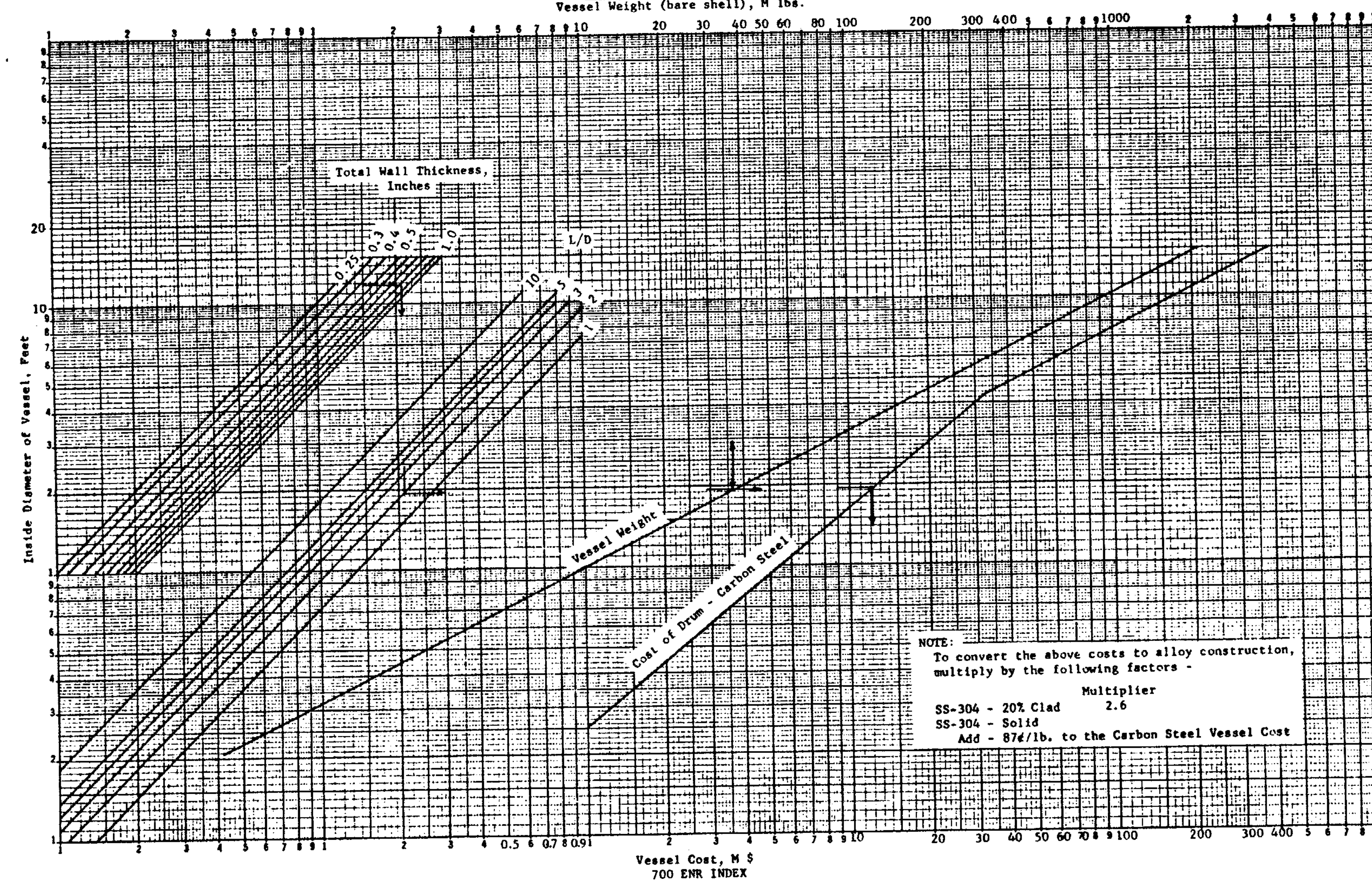
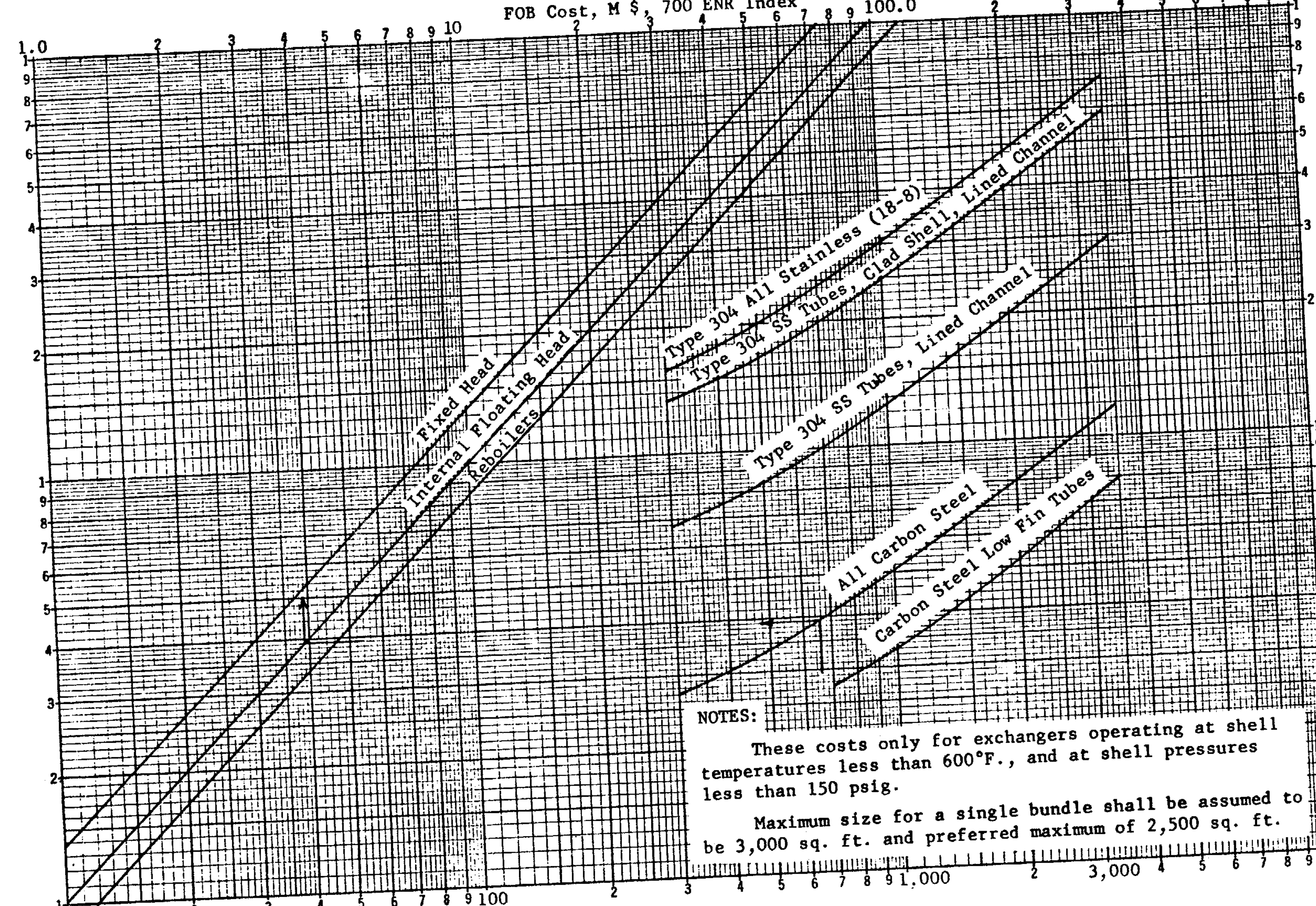


Figure 5 - EXCHANGERS

FOB Cost, M $, 700 ENR Index



Total Heating Outside Area, Sq. Ft.

Newton's book[1] on costs. After you have estimated the individual equipment for preliminary estimates, such as the one you are preparing, it is not necessary to estimate individually items such as piping, instrumentation, etc., to obtain the total cost. Instead, you may use the Hirsch and Glazier correlation[2]. If you want additional detail of this method, you may check the original reference, but, briefly, the procedure, which is based on a mathematical study of several plant designs, utilizes a series of equations to determine the total cost as summarized in Table 6. Use a value of 875 for ENR index to convert the investment obtained by this method to current costs.

With regard to costs other than utilities and equipment, you may use the following values (Table 7). Table 8 gives our standard factors to be applied in arriving at the manufacturing cost of each product or intermediate. It is our standard procedure to charge any intermediate at its net manufacturing cost to the following unit which uses it and then to determine the over-all return and payout on the total investment for the unified process.

We also prepare break-even charts on each

Table 6. PROCESS-INVESTMENT CALCULATION PROCEDURE

For use in preliminary economic evaluations, it is possible to arrive at the total process investment without estimating in detail the instrumentation, piping, insulation, etc. This is done by relating total process investment to basic equipment cost. For your evaluation use the method of Hirsch and Glazier(*2*). This involves a series of equations for installation factors as follows:

$$I = E[A(1 + F_L + F_P + F_M) + B + C]$$

where

I = process investment, battery limits, dollars at 700 ENR index; multiply this by the ENR index ratio to convert to the current cost

E = indirect cost factor representing contractor's overhead and profit, engineering, supervision, and contingencies; for your estimate use 1.4 for E

A = total cost of all battery-limits equipment based on an f.o.b. basis; this cost is exclusive of any incremental cost for alloy materials when such materials are used only because of their corrosion-resisting properties

B = cost of all equipment estimated on an erected basis, such as furnaces, cooling towers, loading stations, etc.

C = incremental cost of alloy materials when used for corrosion resistance; thus, for example, for an alloy pump the cost of a carbon-steel pump of identical design would be included in the basis equipment cost, A, and the incremental alloy cost, (that is cost of alloy pump minus cost of the carbon steel pump) would be included in C

F_L = cost factor for field labor ($F_L \times A$ = total field labor cost)

F_M = cost factor for miscellaneous items ($F_M \times A$ includes the materials cost for insulation, instruments, foundations, structural steel, control buildings, wiring, painting, freight, and field supervision)

F_P = cost factor for piping materials ($F_P \times A$ is the total cost of piping materials including pipe, fittings, valves, hangers and supports, but excluding insulation and labor; these latter items are included in F_L and F_M)

The installation factors may be estimated by the following equations:

$$\log F_L = 0.635 - 0.154 \log A_0 - 0.992\left(\frac{e}{A}\right) + 0.506\left(\frac{f}{A}\right)$$

$$\log F_P = -0.266 - 0.014 \log A_0 - 0.156\left(\frac{e}{A}\right) + 0.556\left(\frac{p}{A}\right)$$

$$F_M = 0.344 + 0.033 \log A_0 + 1.194\left(\frac{t}{A}\right)$$

where

A_0 = A, expressed in thousands of dollars.

e = total heat exchanger cost (less incremental alloy cost)

f = total cost of field-fabricated vessels (less incremental cost of alloy); any vessel with an inside diameter diameter larger than 12 ft. should be considered as field-fabricated unless specifically designated as shop-fabricated

p = total pump plus driver cost (less incremental cost of alloy)

t = total cost of tower shells (less incremental cost of alloy) product or intermediate, charging the projected net return value for its feedstock and crediting its product likewise at projected net return value. I know you are rushed for time; so if you will prepare the chart for the solutions-mixing unit, I will take your manufacturing costs on May 15 and prepare charts for the other units myself. If you have any question on preparing these charts, just refer to either Tyler's book[3] on economics, page 213, or to Aries and Newton[1], pages 203 to 206.

Table 7. LABOR AND MISCELLANEOUS COSTS

Operator labor rate, avg.	\$2.75/hr.
Inhibitor solution	\$1.25/gal.
Kraft bags, 80-lb. capacity	
for pebbled urea	\$150/1,000 bags
for pebbled ammonium nitrate (AN)	\$175/1,000 bags
Coating material for AN	\$12/ton
Platinum	\$85/troy oz.
Copper shot	30¢/lb.
Monoethanolamine (MEA)	25¢/lb.
Acetic acid	10¢/lb.
Sodium hydroxide	3¢/lb.
Reforming catalyst	\$1.00/lb.
Shift catalyst	\$0.50/lb.
NH_3 synthesis catalyst	\$0.60/lb.

Because price changes of feedstocks or products often make an evaluation obsolete, we usually prepare either equations expressing profitability as a function of certain variable costs or nomographs which achieve the same results. Please prepare a nomograph for determining over-all return after U.S. taxes on total investment for the following ranges:

Reformer feed and fuel gas	± 35% of base case (EKW to CEN)
Labor	\$2.75 to \$3.50/hr.
Product values	-20% to +20% of N_2 base value (HHS to CEN)

On product value assume that all product prices vary in relation to their nitrogen content. If you

Table 8. ESTIMATING FACTORS

Investment shall be composed of

Process investment
Allocated utilities (if required)
Storage facilities
Allocated offsites

Direct charges on investment and labor are as follows:

Depreciation:	process including storage, 7.5% straight line
	all other, 5% straight line
Interest:	2% of investment
Insurance and local taxes:	1.5% of total investment
Maintenance material:	50% of maintenance
labor:	50% of maintenance
Maintenance is	3% ammonia process investment
	6% urea process investment
	4% all other process investments
	2% all nonprocess investments
Labor-based overheads*:	79% of operating and maintenance labor
Indirect allocated overheads:	2% of plant investment plus 20% of operating and maintenance labor

Other operating expenses:

Catalyst replacement—as required
Miscellaneous chemicals other than feedstock—as required

*Includes all necessary labor-based assessments and labor supervision plus other overheads which are prorated on a labor basis.

are not familiar with the construction of such graphs, consult either the article by Hill[10] or the book on nomographs by Davis[11].

With regard to capital requirement other than process investment, you may assume allocated general off sites (fences, change houses, guard building, etc.) to be 15% of process investment. Check with Mr. E. K. Watts for utilities availability. You may ignore working capital at this stage.

Our estimates are all prepared on a yearly basis. Amounts for operating costs and profits are rounded off to the nearest $100 in the final tabulations, and figures for investment are rounded to the nearest $1,000.

I. M. Tight

IMT:jeb

INTERDIVISION MEMORANDUM 62-19

DATE: May 4, 1962
SUBJECT: Utilities Costs

TO: C. E. Newblood, Junior Process Engineer
FROM: E. K. Watts, Utilities Superintendent, Oilville Plant

In reply to Dr. Major's request, I have prepared some figures on cost of utilities for your use.

Refinery fuel gas	16¢/1 X 10^6 B.t.u.
Refinery hydrogen-rich gas	20¢/1 X 10^6 B.t.u.
Natural gas (1,000 B.t.u./cu. ft.	20¢/1 X 10^6 B.t.u.
Steam, sat'd. (500 lb./sq. in. or less)	60¢/1,000 lb.
Cooling water*	2¢/1,000 gal.
Process water (boiler feed water quality)	14¢/1,000 gal.
Power	0.75¢/kw.-hr.

*Cooling water from cooling towers is available at 85°F. and must be returned to towers at temperature no higher than 115°F. You may use a fouling factor of 0.001 when calculating water film coefficient.

For preliminary estimating purposes, you may neglect the cost of compressed air used for instrumentation purposes or for tank unloading. Assume that sufficient installed capacity for all utilities is available and that no allocated investment for utilities is required.

E. K. Watts

EKW:pac

INTERDIVISION MEMORANDUM 62-20

DATE: May 4, 1962
SUBJECT: Agricultural Products Sales Projections

TO: C. E. Newblood, Junior Process Engineer
FROM: Hiram H. Seed, Agricultural Sales Research Manager

As Dr. Major requested, we have prepared a market projection for the initial nitrogen-based products which we hope to sell. Despite the over-all excess capacity in this line of products, due to a combination of our favorable feedstock situation and economical shipping distances for the products, I suggest the following yearly sales pattern and net return values for the products after selling expense has been deducted:

	Short tons/ annum	Price, $/ton
Liquid anhydrous ammonia, as such	8,808	83.00
Ammonium nitrate pebbled and coated, in bags, 33.6% N_2	60,425	61.00
Urea, pebbled, in bags	33,000	90.00
Nitric acid, for sale	None	
Nitrogen fertilizer solutions, as N_2	35,000*	125.00*

*Nitrogen fertilizer solutions are sold on a basis of nitrogen content; that is, we plan to sell 35,000 tons of N_2 in this form, although several different ratios may be sold.

For purpose of your estimate, assume a single composition for fertilizer solutions as follows:

	Wt. %
Free ammonia	34.0
Ammonium nitrate	60.0
Water	6.0
	100.0

Any variation in the compositions, when actual sales pattern is known, will require minor adjustments in sales of pebbled ammonium nitrate and anhydrous ammonia to achieve a balance.

Hiram H. Seed

HHS:eet

INTERDIVISION MEMORANDUM 62-21

DATE: May 4, 1962
SUBJECT: Properties of Chemicals

TO: C. E. Newblood, Junior Process Engineer
FROM: Dalton R. Boyle, Physical Sciences Supervisor

At Dr. Major's request, I have assembled some information on the properties of compounds with which you will be working. Attached hereto are tables and figures giving vapor pressures, densities, viscosities, heats of mixing, and solubilities of several compounds. If you should find need for data not listed, consult Perry's Handbook or any other standard available references. You may assume that the specific heats of water, liquid ammonia, and ammonium nitrate are constant within the range that you will be processing at 1.0, 1.2 and 0.3 B.t.u./(lb.) (°F.), respectively. Assume the specific heat of mixtures proportional to their composition.

Please remember that aqueous ammonium nitrate solutions require use of at least either solid or clad type-304 stainless steel for processing equipment. The finished fertilizer solutions do also.

Dalton R. Boyle

DRB:cl
Attachments (4)
Figures 6 through 8
Table 9

Table 9. PROPERTIES OF ANHYDROUS AMMONIA AT VARIOUS TEMPERATURES*

Temperature °F.	Vapor pressure lb./sq. in. gauge	Liquid density lb./cu. ft.	Liquid density lb./U.S. gal.	Specific volume†	Specific gravity‡	Latent heat B.t.u./lb.	Viscosity Mpoises
-28	0.0	42.57	5.69	18.0	0.682	589.3	
-20	3.6	42.22	5.64	18.4	0.675	583.6	
-10	9.0	41.78	5.59	18.8	0.669	576.4	
0	15.7	41.34	5.53	19.3	0.663	568.9	
10	23.8	40.89	5.47	19.8	0.656	561.1	
20	33.5	40.43	5.41	20.2	0.648	553.1	
30	45.0	39.96	5.34	20.5	0.641	544.8	
40	58.6	39.49	5.28	21.1	0.633	536.2	1,880
50	74.5	39.00	5.21	21.6	0.625	527.3	
60	92.9	38.50	5.14	22.0	0.617	518.1	
70	114.1	38.00	5.08	22.5	0.609	508.6	1,592
80	138.3	37.48	5.01	22.9	0.600	498.7	
90	165.9	36.95	4.94	23.4	0.592	488.5	
100	197.2	36.40	4.87	23.8	0.583	477.8	1,306
110	232.3	35.84	4.79	24.2	0.573	466.7	
120	271.7	35.26	4.71	24.6	0.565	455.0	
130	315.6	34.66	4.63	25.5	0.555	443	1,028
140	364.4	34.04	4.55	26.4	0.545	430	

All values except viscosity taken from Natl. Bur. Standards Circ. 142(7)*. Viscosity by Carmichael and Sage *(8)*.

†Specific volume of gas at 1 atm., cu. ft./lb.

‡Specific gravity of liquid compared with that of water at 4° C.

Figure 6

VAPOR PRESSURE, VISCOSITY AND SPECIFIC GRAVITY OF A NITROGEN FERTILIZER SOLUTION

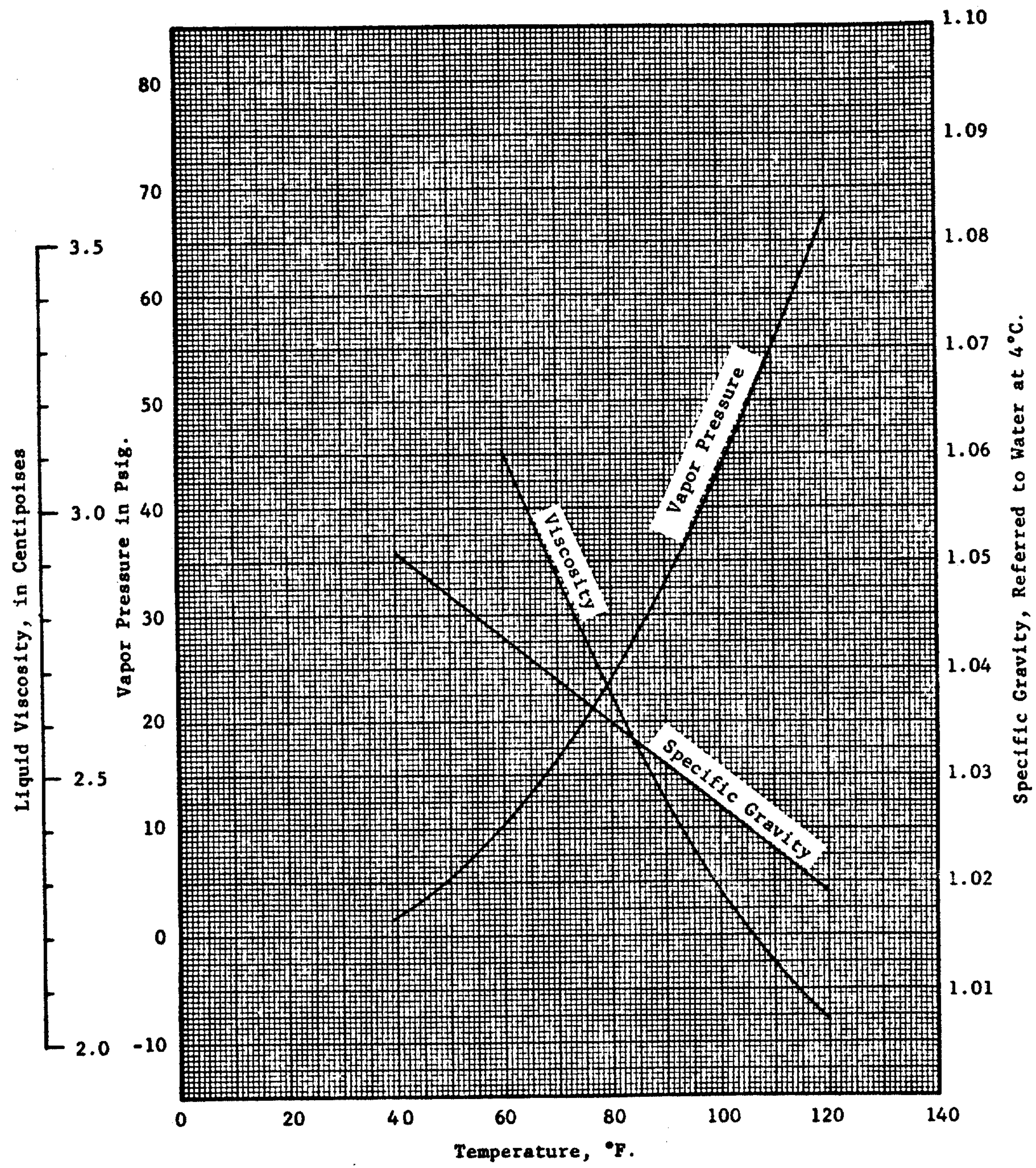
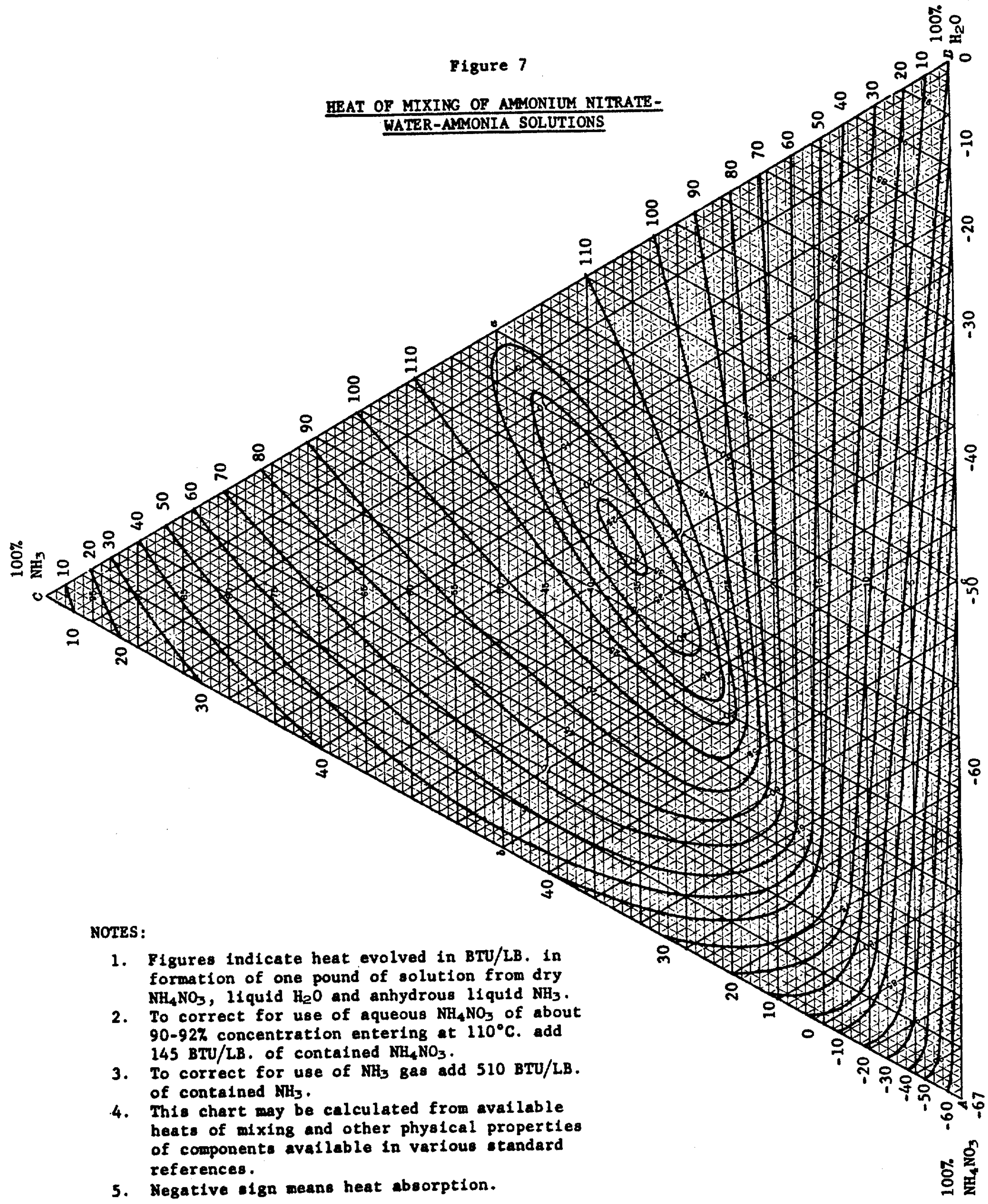


Figure 7

HEAT OF MIXING OF AMMONIUM NITRATE-WATER-AMMONIA SOLUTIONS

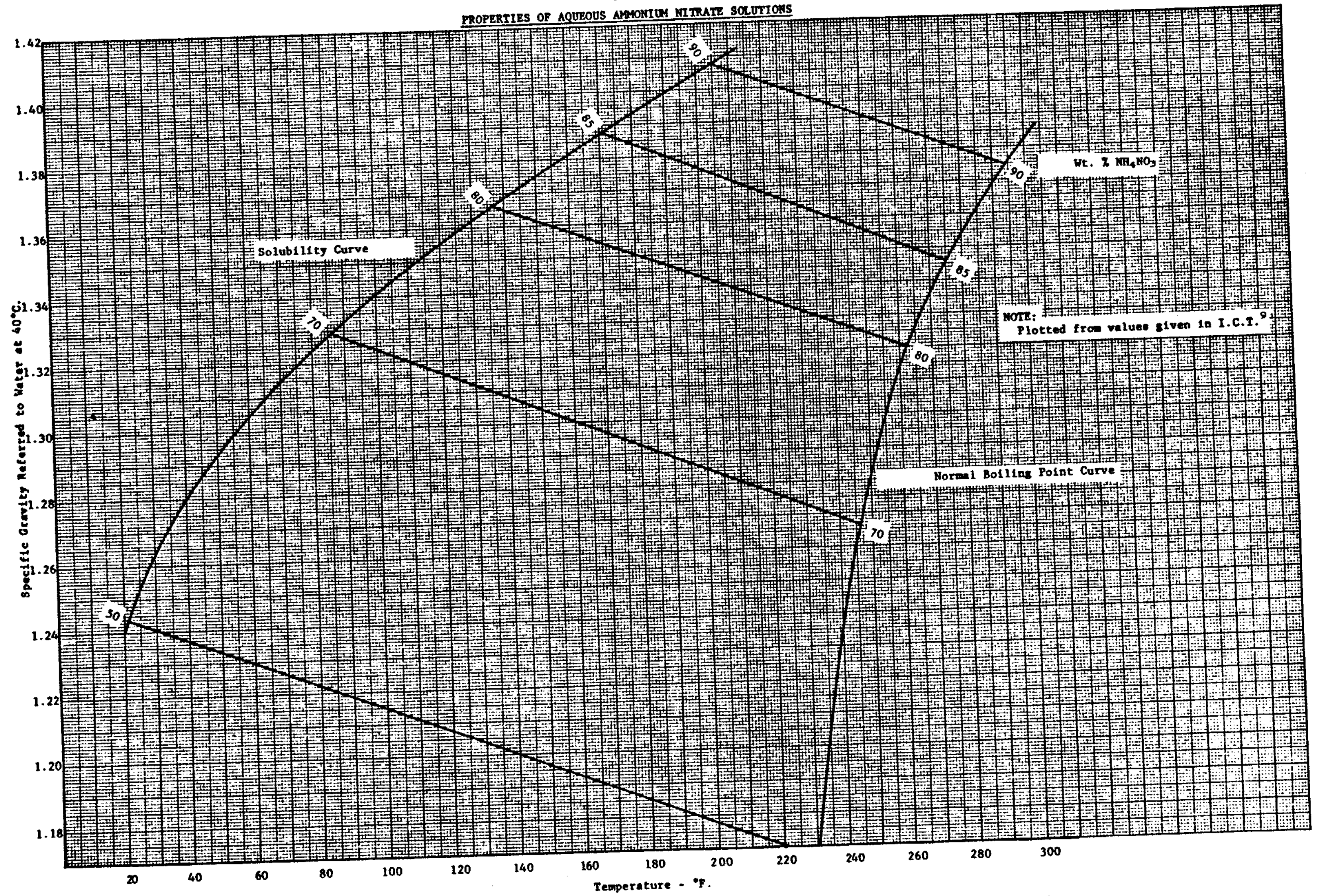


NOTES:

1. Figures indicate heat evolved in BTU/LB. in formation of one pound of solution from dry NH_4NO_3, liquid H_2O and anhydrous liquid NH_3.
2. To correct for use of aqueous NH_4NO_3 of about 90-92% concentration entering at 110°C. add 145 BTU/LB. of contained NH_4NO_3.
3. To correct for use of NH_3 gas add 510 BTU/LB. of contained NH_3.
4. This chart may be calculated from available heats of mixing and other physical properties of components available in various standard references.
5. Negative sign means heat absorption.

Figure 8

PROPERTIES OF AQUEOUS AMMONIUM NITRATE SOLUTIONS



LITERATURE CITED

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SOLUTIONS JUDGING CHECK LIST

I. NONTECHNICAL

A. Appearance and English

1. Over-all Impression (Format)
2. English
   a. Grammar
   b. Spelling
3. Neatness
   a. Body of Report
   b. Appendix
   c. Graphs and Tables
   d. Drawings

B. Organization

1. Report
   a. Cover Letter
   b. Table of Contents
   c. Summary
   d. Report Proper
      (1) Presentation Sequence
      (2) Pertinence of Included Material
      (3) Conclusions
   e. Appendix
      (1) Nomenclature
      (2) Calculations
      (3) References
2. Time—Correct Emphasis on Each Phase of the Problem

C. Clarity and Understandability

1. Report
2. Calculations and Technical Methods
   a. Body of Report
   b. Appendix
3. Drawings, Graphs, and Tables

II. TECHNICAL

A. Technical Methods

1. Correctness
2. Applicability
3. Desirability (Best Method Used)
4. Validity of Assumptions
5. Justification of Assumptions
6. Validity of Conclusions
7. Accuracy of Mathematics

B. Originality

1. Design
2. Technical Methods
3. Assumptions
4. Presentation

C. Student Understanding

1. Over-all Grasp of Problem
2. Technical Methods
3. Engineering Concepts