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SUBJECT: Estimate of the Cost of Producing Nitrogen 15
by Chemical Exchange: Determination of
Minimum Cost Nitrox System

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FROM: B. B. Klima

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ESTIMATE OF THE COST OF PRODUCING NITROGEN 15
BY CHEMICAL EXCHANGE: DETERMINATION OF
MINIMUM COST NITROX SYSTEM

An estimate(a) has been made of the cost of nitrogen 15 based on the "nitrox" system(b). That estimate was based on preliminary tests made by Taylor and Spindel(c). Since that time additional work has been done both by Taylor and Spindel at Columbia University and by the Isotope Separations Section, Materials Chemistry Division, Oak Ridge National Laboratory. It is the purpose of this cost estimate to determine the system conditions which will give a minimum cost of producing nitrogen 15. The separation factor (alpha) and the concentration of product sulfuric acid both vary as the molarity of the nitric acid is varied (see Figure 1). Estimates were made of three systems using 7, 10, and 15 molar nitric acid as the aqueous phase.

One gram of nitrogen 15 product produced at the rate of one pound N^{15} per day using 7 molar nitric acid will cost \$3.93 (see Figure 2 and Table 1) which is 10% less than the cost using 10 molar nitric acid and much less than the costs using 15 molar acid. The plant costs are considerably lower for the 7 molar process than for the other two as noted in Table 1.

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- (a) B. B. Klima, W. T. Ward, and J. S. Drury, Estimate of the Cost of Producing Nitrogen-15 by Chemical Exchange: Nitric Acid--Nitric Oxide System Using Sulfur Dioxide Reflux, ORNL CF-55-1-22 (January 14, 1955).
- (b) Isotopic Exchange Between Nitric Acid and Nitric Oxide Using Sulfur Dioxide Product Reflux.
- (c) T. L. Taylor and W. Spindel, Columbia University, originators of the process.

Fig. 1. EFFECT OF MOLARITY OF NITRIC ACID ON SEPARATION FACTOR AND SULFURIC ACID CONCENTRATION

Fig.2. EFFECT OF MOLARITY OF NITRIC ACID ON PRODUCT N15 COST

TABLE 1. COSTS OF PLANT AND PRODUCT
AT THREE NITRIC ACID MOLARITIES

	Concentration of Nitric Acid		
	7 molar	10 molar	15 molar
Cost per pound of N_2O_5 (1) (3)	\$ 1,784	\$ 1,948	\$ 3,663
Cost per gram of N_2O_5 (1) (3)	3.93	4.29	8.08
Total Plant Investment (2)	767,829	985,854	3,424,288
Total Physical Plant (2)	326,299	426,498	1,552,745
Installed Equipment Cost (6)	137,679	179,957	655,167
Total Annual Variable Costs (4)	631,842	663,540	871,761
Total Annual Fixed Costs (5)	276,210	317,717	784,275

- (1) Credit for sale of by-product sulfuric acid and waste nitric acid assumed.
 (2) See Table 2 for details.
 (3) See Table 3 for details.
 (4) See Table 4 for details.
 (5) See Table 5 for details.
 (6) See Table 6 for details.

TABLE 2. TOTAL PLANT INVESTMENT (a)

Code	Item	Concentration Nitric Acid		
		7M	10M	15M
A	Installed equipment (b)	\$137,679	\$179,957	\$ 655,167
B	Process piping	82,607	107,974	393,100
C	Instrumentation	19,275	25,194	91,723
D	Process buildings	41,304	53,987	196,550
E	Laboratory furniture and equipment	4,130	5,399	19,655
F	Service facilities	41,304	53,987	196,550
G	Total Physical Plant	\$326,299	\$426,498	\$1,552,745
H	Engineering	130,520	170,599	621,098
I	Site development	20,652	26,994	98,275
J	Preoperational costs	130,520	170,599	621,098
K	Contingency	81,575	106,625	388,186
L	Working capital	78,263	84,539	142,886
M	Total Plant Investment	\$767,829	\$985,854	\$3,424,288

- (a) See Page 8, ORNL CF-55-1-22 for estimating details.
 (b) See Table 6 for details.

TABLE 3. PRODUCT COST^(a)

	Concentration of Nitric Acid		
	7M	10M	15M
Total annual variable costs (b)	\$631,842	\$663,540	\$ 871,761
Total annual fixed costs(c)	276,993	318,562	785,704
Total Annual Costs	\$908,835	\$982,102	\$1,657,465
Cost per pound (no credit)	2,490	2,691	4,541
Cost per gram (no credit)	5.49	5.93	10.01
Credit per pound	706	743	878
Net per pound	1,784	1,948	3,663
Net per gram	3.93	4.29	8.08

(a) See Page 9, ORNL CF-55-1-22 for estimating details.

(b) See Table 4 for details.

(c) See Table 5 for details.

TABLE 4. ANNUAL VARIABLE COSTS^(a)

Item No.	Item	Concentration of Nitric Acid		
		7M	10M	15M
N	Raw materials(b)	\$364,536	\$383,750	\$458,706
O	Labor and supervision(c)	201,480	201,480	201,480
P	Utilities	19,578	25,590	93,165
Q	Maintenance	16,315	21,325	77,637
R	Supplies	1,632	2,133	7,764
S	Packaging, storage, shortage, etc.	28,301	29,262	33,009
T	Total Variable Costs	\$631,842	\$663,540	\$871,761

(a) See Page 8, ORNL CF-55-1-22 for estimating details.

(b) See Table 7 for details.

(c) Assumed same as for ORNL CF-55-1-22.

TABLE 5. ANNUAL FIXED COSTS^(a)

Code	Item	Concentration of Nitric Acid		
		7M	10M	15M
U	Depreciation	\$103,435	\$135,197	\$492,210
V	Interest charge on total fixed capital	6,896	9,013	32,814
W	Interest charge on working capital	783	845	1,429
X	Payment in lieu of taxes	6,896	9,013	32,814
Y	Overhead	158,983	164,494	226,437
Z	Total annual fixed costs	\$276,993	\$318,562	\$785,704

(a) See Page 9, ORNL CF-55-1-22 for estimating details.

TABLE 6. INSTALLED PROCESS EQUIPMENT COSTS

	Concentration of Nitric Acid		
	7M	10M	15M
Columns	\$ 71,664	\$110,792	\$547,762
Pumps	22,695	24,575	43,735
Tanks	36,390	37,660	55,300
Heat exchangers	6,930	6,930	8,370
Total installed equipment costs	\$137,679	\$179,957	\$655,167

TABLE 7. RAW MATERIALS COSTS PER DAY

Raw Materials	Concentration of Nitric Acid		
	7M	10M	15M
SO ₂	\$ 895.07	\$ 945.16	\$ 1,128.87
HNO ₃	81.74	81.74	81.74
Air	8.42	10.82	28.58
Process water	0.37	0.25	0.33
Cooling water	13.13	13.40	17.21
	\$ 998.73	\$ 1,051.37	\$ 1,256.73
Cost per 365-day year	\$364,536	\$383,750	\$458,706

Process Description

The same process was used in this estimate that was used in the previous Nitrox estimate⁽¹⁾. The flow diagrams for the three estimates would, therefore, be identical with each other and with Figure 1, ORNL CF-55-1-22, except that due to the low separation factor for the 15 molar nitric acid system two exchange columns had to be specified in series for each of the exchange sections which doubled the number of pumps and tanks for that part of the system. This accounts for part of the increased cost for that plant. The characteristics of the three plants are given in Table 8.

The following have been specified to be the same as in the previous estimate⁽¹⁾:

- a. The same terminal concentrations of nitrogen 15 for each of the enrichment and the stripping sections.
- b. The same cost estimating methods and costs of raw materials.
- c. All of the criteria except as is noted in Table 9.

Further laboratory testing has proven the existence of two product reflux reactions as follows:

Reaction "a" takes place primarily when the aqueous phase has low nitric acid molarity and reaction "b" then takes over at the higher nitric acid molarities. In each estimate the reacting quantities were calculated based on these reactions and the known composition of the gases in equilibrium with the liquid.

(1) ORNL CF-55-1-22.

TABLE 8. CHARACTERISTICS OF PLANTS

	Concentration of Nitric Acid		
	7M	10M	15M
Number of Stages			
3rd enrichment section (product)	117.6	150.3	387.0
2nd enrichment section	45.1	60.4	155.4
1st enrichment section	34.6	43.9	113.0
Stripping section	31.6	36.2	79.4
Column Diameter--inches			
3rd enrichment section	3	4	6
2nd enrichment section	8	8	12
1st enrichment section	10	12	18
Stripping section	10	12	18
Column Height--feet			
3rd enrichment section	71	90	290
2nd enrichment section	45	60	233
1st enrichment section	43	66	235
Stripping section	40	54	165

TABLE 9. CRITERIA USED WHICH DIFFERED FROM THAT USED
IN PREVIOUS ESTIMATE (ORNL CF-55-1-22)

	Concentration of Nitric Acid		
	7M	10M	15M
Separation factor	1.060	1.047	1.018
Gaseous phase in equilibrium with nitric acid in aqueous phase			
Ratio - NO ₂ to NO	0.04	0.38	9.1
H ₂ O vapor %	2	2	2
Dissolved NO aqueous phase lbs per gal	0.0834	0.1252	0.1877