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NEW PRODUCT PRICING

MASTER

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GAS CENTRIFUGE ENGINEERING

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NEW PRODUCT PRICING*

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ABSTRACT

One of the most uncertain elements in budget planning is estimating production costs of items that have heretofore only been produced in prototype configurations and quantities. This paper examines the design and development of a mathematical model which computes appropriate prices for new and unique products. The resulting model offers a producer a fair return on his investment and the consumer a fair purchase price.

INTRODUCTION

President Carter announced in April 1977 that the next U.S. uranium enrichment facility would incorporate the recently developed centrifuge enrichment process. The basis of the enrichment process is the gas centrifuge machine which will account for almost one-third of the total plant cost [4]. This machine performs the basic enrichment process whereby gaseous uranium hexafluoride is fed into a high speed rotor inside an evacuated casing. The gas accelerates to approximately the speed of the rotor. Centrifugal force causes the heavier U-238 molecules to move closer to the wall of the rotor, producing partial separation of the U-235 and U-238 isotopes.

Since the desired enrichment is not obtained in a single centrifuge, several machines must be connected in a series. Only a small amount of gas will flow through a single centrifuge. Therefore, a large number of machines must be connected in parallel to achieve the total flow necessary for a single stage of enrichment in a large capacity plant.

The most complex and costly components of the facility are unique, and to date, have only been fabricated in laboratory quantities so that no commercial source or price exists. That source must be developed at a reasonable cost for the centrifuge plant to be completed within budget. UCCND is presently conducting an extensive effort to determine those "reasonable" prices.

*Based on work performed at the Oak Ridge Gaseous Diffusion Plant operated by Union Carbide Nuclear Division for the U.S. Department of Energy under U.S. Government Contract W-7405-eng-26. By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive royalty-free license in and to copy-right covering this paper.

This paper derives a model used to estimate the cost of these new and unique gas centrifuge enrichment plant components that have heretofore only been produced in prototype configurations and quantities. The model offers a private component manufacturer an equitable return on his investment and a fair price to the purchaser.

The derivation results in a direct solution of the required capital recovery component of unit price under conditions of private financing in which both the debt/equity ratio and the rates of return on debt and equity are fixed throughout the project life. In this method debt and equity are retired in fixed proportion each year, using the surplus which remains after payment of taxes as returns to debt and equity. The approach is used to form the recursion relationship between the remaining investments of successive years and to evaluate this by discounted constant dollar cash flows over the project life such that the final investment is zero.

The model is designed to accept either one of two basic types of contract - the fixed price or the cost type. The fixed price capital recovery model will be examined first, then the cost type model will then be derived from the fixed price. The paper is concluded by examining an example problem which is applied to each of the contract types.

FIXED PRICE CAPITAL RECOVERY MODEL

The fixed price contract is analogous to those used in commercial business whereby the vendor agrees to deliver a product at a particular schedule for a fixed price. The model's basic premise is that cost will equal revenues of the life of the project, or:

$$\sum_{i=1}^N (C_i - R_i) = 0 \tag{1}$$

where:

- C = cost
- R = revenue
- i = time index
- N = campaign length

Further define:

- CC = Capital cost
- CO_i = Capital investment at end of year i

MOEW

L = Labor cost (direct and indirect)
 M = Material cost (direct and indirect)
 T = Training cost
 G = G and A cost
 S = State/local taxes and insurance
 I = Interest payment
 D = Dividends paid
 IT = Income tax
 ITC = Investment tax credit
 DP = Depreciation for tax purposes
 r = After tax discount rate
 r_t = Composite state and federal income tax rate
 r_d = Interest rate on debt
 r_e = Rate of return on equity
 d = Fraction of investment financed through debt
 q = Production quantity
 P = Unit price
 PV = Present value

The costs for year i will be:

$$C_i = CC_i + L_i + M_i + T_i + G_i + S_i + I_i + D_i + IT_i \quad (2)$$

where:

$$IT_i = r_t (R_i - L_i - M_i - T_i - G_i - S_i - I_i - DP_i) - ITC_i \quad (3)$$

or:

$$C_i = CC_i + (1-r_t) (L_i + M_i + T_i + G_i + S_i + I_i) + (r_t) (R_i) + D_i - (r_t) (DP_i) - ITC_i$$

Substituting this into Equation 1 results in:

$$\sum_{i=1}^N [CC_i + (1-r_t) (L_i + M_i + T_i + G_i + S_i) + (1-r_t) I_i + D_i - r_t DP_i - ITC_i - (1-r_t) R_i] = 0 \quad (4)$$

Separate the cost of financing the project (b) from the other costs and revenues of Equation 4 such that:

$$\sum_{i=1}^N (a_i + b_i) = 0. \quad (5)$$

Where:

$$a_i = CC_i + (1-r_t) (L_i + M_i + T_i + G_i + S_i) - r_t DP_i - ITC_i - (1-r_t) R_i \quad (6)$$

and,

$$b_i = (1-r_t) I + D_i \quad (7)$$

Interest (I) and dividends (D) are both functions of the previous year's cash flows. Since the costs of money are constrained by the debt rate (r_d) and equity rate (r_e) there will be required annual payments of:

$$I_i = (r_d) (d) (CO_{i-1}) \quad (8)$$

and:

$$D_i = (r_e) (1-d) (CO_{i-1}) \quad (9)$$

where:

$$CO_{i-1} = \sum_{j=1}^{i-1} (a_j + b_j)$$

Substituting Equations 8 and 9 into Equation 7:

$$b_i = [(1-r_t) (r_d) (d) + r_e (1-d)] CO_{i-1} \quad (10)$$

Define the weighted after-tax cost of capital as the discount rate:

$$r = (1-r_t) (r_d) (d) + (r_e) (1-d) \quad (11)$$

Substituting into Equation 10:

$$b_i = (r) (CO_{i-1}) = (r) \sum_{j=1}^{i-1} (a_j + b_j) \quad (12)$$

or:

$$b_i = (r) \sum_{j=1}^{i-1} a_j + (r) \sum_{j=2}^{i-1} b_j$$

Solving this recursive equation yields:

$$b_i = (r) \sum_{j=1}^{i-1} a_j (1+r)^{i-j-1} \quad (13)$$

Substituting into Equation 5:

$$\sum_{i=1}^N [a_i + (r) \sum_{j=1}^{i-1} a_j (1+r)^{i-j-1}] = 0 \quad (14)$$

Separate the revenue term from the rest of the terms in Equation 6 so that:

$$a_i = H_i - (1-r_t) R_i \quad (15)$$

where:

$$H_i = CC_i + (1-r_t) (L_i + M_i + T_i + G_i + S_i) - r_t DP_i - ITC_i \quad (16)$$

Annual revenues equal the number produced times the selling price:

$$R_i = (P) (q_i) \text{ or: } a_i = H_i - (1-r_t) (P) (q_i) \quad (17)$$

and substituting into Equation 14:

$$\sum_{i=1}^N [H_i - (1-r_t) (P) (q_i) + (r) \sum_{j=1}^{i-1} [(H_j - (1-r_t) (P) (q_j)) (1+r)^{i-j-1}]] = 0 \quad (18)$$

Solving Equation 18 for unit price (P):

$$P = \frac{\sum_{i=1}^N [H_i + (r) \sum_{j=1}^{i-1} H_j (1+r)^{i-j-1}]}{(1-r_t) [\sum_{i=1}^N q_i + (r) \sum_{j=1}^{i-1} q_j (1+r)^{i-j-1}]}$$

or:

$$P = \frac{\sum_{i=1}^N H_i (1+r)^{N-i}}{(1-r_t) \sum_{i=1}^N q_i (1+r)^{N-i}}$$

Dividing both numerator and denominator by $(1+r)^N$:

$$P = \frac{\sum_{i=1}^N H_i (1+r)^{-i}}{(1-r_t) \sum_{i=1}^N q_i (1+r)^{-i}} \quad (19)$$

Note the following:

- The $(1+r)^{-i}$ factor present values all items in the cash flow stream.
- The depreciation term (DP) can be any combination of depreciation methods.

In general, Equation 19 may be written:

$$\text{Unit price} = \frac{PV(\text{costs}) - (r_t) PV(\text{costs for tax purposes})}{(1-r_t) PV(\text{units sold})} \quad (20)$$

Where Equation 20 is to be applied to all of the costs, including capital, which are to be recovered in the selling price. The discount rate (Equation 11) may be defined as the weighted after-tax cost of money.

Equation 20 results in a fixed unit price over the total project life or a firm-fixed price (FFP) cost model. The FFP commits a vendor to a certain price unless there are subsequent changes to the contract. Fixed price contracts account for over 70% of the dollar value of Department of Defense (DOD) contract awards to domestic business [1].

COST TYPE CAPITAL RECOVERY MODEL

The cost type contract allows the vendor to recover all his allowable costs as they are incurred plus a fee which is set before the contract is signed. The effect of this type contract is to remove vendor cost risks.

Since the vendor is reimbursed for all costs as they are incurred there is theoretically no need for vendor investment or financing and, therefore, no interest or return on equity. If any such costs are incurred they must be recovered in the fee as well as any other expenses which may be disallowed in the calculation of cost. The classification of particular costs have been outlined in great detail in the weighted profit/fee guidelines of DOE's procurement regulations [6].

Table 1 is a summary of those guidelines as allowable and non-allowable costs.

TABLE 1
SUMMARY OF ALLOWABLE/NON-ALLOWABLE COSTS
IN COST TYPE CONTRACTS

	Allowable	Non-allowable
Direct labor	x	
Indirect Labor	x	
Direct Material	x	
Indirect Material	x	
Capital Recovery	x	
G and A	x	
State/Local Taxes	x	
Return on Equity		x
Interest		x
Federal Taxes		x

Equation 20 was modified to calculate a fee that will allow a vendor to recover his total costs (allowable and non-allowable) in cost type contracting.

The only changes to Equation 20 from a fixed price to a cost type contract is that a vendor can recover his capital investment on an annual depreciation rate rather than on a production rate, and the cost of taxes or financing is non-allowable. The Armed Services Procurement Regulations (ASPR) restricts this recovery to standard IRS depreciation guidelines [5]. Therefore, if the assumption is made that capital is recovered at the same rate as the IRS depreciation schedule, Equation 20 becomes:

$$\text{Cost Contract Unit Price} = \frac{(1-r_t) \text{ present value of costs}}{(1-r_t) \text{ present value of units sold}} \quad (21)$$

or:

$$\text{Cost Contract Unit Price} = \frac{\text{Present value of costs}}{\text{Present value of units sold}} \quad (22)$$

To determine the fee required to cover cost of financing and return on equity the discount rate r is allowed to go to zero and Equation 22 becomes:

$$\text{Unit price without financing/equity return cost} = \frac{\text{cost}}{\text{units sold}} \quad (23)$$

The fixed fee must cover the non-allowable taxes and financing/equity costs such that $(1 + \text{fee})$ (unit price without financing/equity cost) = unit price under a fixed price, or:

$$\text{Fee} = \frac{\text{Unit price under a fixed price}}{\text{Unit price without financing/equity cost}} - 1 \quad (24)$$

Substituting Equations 20 and 23 into Equation 24 results in:

$$\text{Fee} + 1 = \frac{[PV(\text{costs}) - (r_t) PV(\text{costs for tax purposes})] (\text{units})}{[(1-r_t) PV(\text{units})] (\text{costs})} \quad (25)$$

THE QUESTION OF INFLATION

At this point it should be pointed out that the preceding derivation did not consider inflation, except as reflected in current debt and equity rates. The price resulting from the foregoing analyses as well as all costs are in constant or base year dollars. As used here, constant dollars refer to the sum of money that would be exchanged for goods and services in the base or reference year. If inflation were considered, the cost stream as well as the unit price would be in current or as-spent dollars. Current dollars represent the sum of money that is exchanged for goods and services at the actual time of purchase.

Inflation may be included in the analyses by considering the relationship between current and constant dollars as:

$$\text{Cost in current dollars} = (1+I_r)^i \text{ cost in constant dollars} \quad (26)$$

where I_r is the rate of inflation.

I_r is a function of both time and the individual cost elements. For example, the value of I_r for a service may be determined by extrapolating from consumer price index data or from union contract agreements for future wage rates. The value of I_r for raw material may be estimated by extrapolating from one or more sets of wholesale price indices.

Jelen [12] advocated a current dollar technique (based on Equation 26) as early as 1956. In more recent times the use of inflation has been suggested in power plant studies [13], *Harvard Business Review* [8, 11], *AIIE Transactions* [2], and is required by Army program evaluations [14]. On the other hand, Grant and Ireson [9] as well as Fabrycky and Torgersen [7] recommend that engineering economic analyses be carried out in terms of constant dollars.

Due to the unpredictability of the inflation factor, the complexity of application, the lack of suitable price indices for new manufacturing process, and DOE desires for estimates in this year dollars, the constant dollar calculation was adopted by the author. However, plans are to add provisions for inflation in future expansions of the cost estimation model. The question as to consider or not consider the effect of inflation may be related to Baron Rothschild's opinion that he knew of only two men who really understood money - an obscure clerk in the Bank of France and one of the directors of the Bank of England. "Unfortunately", he added, "they disagree".

FIXED PRICE - COST TYPE EXAMPLE PROBLEM

Table 2 details an example cash flow problem which will be applied to (a) a fixed price contract and (b) a cost type contract.

a. The resulting cash flows, totals, present values and unit price for a fixed price contract are shown as Table 3. The resulting \$39.59 unit price will generate a 15% equity return on one-half of the

investment and pay the 10% interest charge on the remaining.

b. The cost type cash flows, totals, present values and unit price are shown as Table 4. For this type contract, a unit price of \$31.33 will cover a 15% equity return and pay the 10% interest charge.

The price difference between the fixed price and the cost type results from the earlier repayment of capital investment in the cost type. The result is about \$45,000 less in financing and equity return costs in the cost type case.

Shown in Table 5 is a comparison of annual capital returns for the two cases. The fixed price capital returns are the ratios of annual to total production times the total capital writeoff. The cost type capital return is the annual IRS depreciation.

CONCLUSIONS

This paper provides a model for estimating the cost of new and unique components that have heretofore only been produced in prototype configurations and quantities. The model offers the manufacturer a return on this investment based on fixed rates of return on debt by holding a fixed debt/equity ratio throughout the contract life.

The estimating method with its resulting capital recovery models serve four main purposes in the procurement of gas centrifuge enrichment plant components:

1. Estimate the cost of components required for the Gas Centrifuge Enrichment Plant.
2. Estimate the cost of replacement parts.
3. Evaluate vendor bids for the initial plant components and replacement parts.
4. Evaluate and monitor vendor spending during the procurement contract life.

This pricing model and its basic assumptions will undoubtedly undergo a number of iterations prior to its final evaluation as a complete pricing model. However, the basic concept of fixed debt to equity and return to debt and equity to determine price is expected to be retained.

- TABLE 2
EXAMPLE PROBLEM - PARAMETERS

Debt fraction $d = 0.50$	Debt rate $r_d = 0.10$
Effective income tax rate $r_t = 0.48$	Equity rate $r_e = 0.15$
Discount rate $r = (1-0.48) (0.50) (0.10) + (1-0.50) (0.15) = 0.1010$	
Capital requirements \$100,000 in Year 1: \$250,000 in Year 2	
Labor and material	\$10,000 in Year 2 \$25,000 in Year 3 \$35,000 in Years 4 and 5
State/Local taxes 5% of acquisition cost	
Capital depreciation sum of years	
Delivery schedule	1,000 Units in Year 2 4,000 Units in Year 3 6,000 Units in Years 4 and 5

TABLE 3
EXAMPLE PROBLEM - FIXED PRICE ESTIMATE

<u>Year i</u>	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Total</u>	<u>Present Value</u>
Discount Factor	1.0000	0.9083	0.8249	0.7493	0.6805	0.6181		
Capital Requirements		100,000	250,000				350,000	297,055
Labor/Material			10,000	25,000	35,000	35,000	105,000	72,433
State/Local Taxes			5,000	17,500	17,500	17,500	57,500	39,963
Capital Depreciation			40,000	155,000	103,333	51,607	350,000	251,391
Delivery Schedule			1,000	4,000	6,000	6,000	17,000	11,614

$$\text{Unit Price} = \frac{297,055 + 72,433 + 39,963 - 0.48 (72,433 + 39,963 + 251,391)}{(1-0.48) 11,614}$$

$$\text{Unit Price} = \$39.59$$

- TABLE 4
EXAMPLE PROBLEM - COST TYPE ESTIMATE

<u>Year i</u>	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Total</u>	<u>Present Value</u>
Discount Factor	1.0000	0.9083	0.8249	0.7493	0.6805	0.6181		
Capital Requirements		100,000	250,000				350,000	297,055
Labor/Material			10,000	25,000	35,000	35,000	105,000	72,433
State/Local Taxes			5,000	17,500	17,500	17,500	57,500	39,963
Delivery Schedule			1,000	4,000	6,000	6,000	17,000	11,614
Capital Depreciation			40,000	155,000	103,333	51,667	350,000	251,391

$$\text{Unit Price} = \frac{251,391 + 72,433 + 39,963 - 0.48 (72,433 + 39,963 + 251,391)}{(1-0.48) 11,614}$$

$$\text{Unit Price} = \$31.33 \quad \text{Total Contract Price} = (\$30.56) (17,000) = \$532,621$$

$$\text{Unit price without equity return and financing costs} = \frac{350,000 + 105,000 + 57,500}{17,000} = \$30.15$$

$$\text{Fixed fee to cover equity return and financing costs} = \frac{31.33 - 30.15}{30.15} = 3.9\%$$

TABLE 5
ANNUAL CAPITAL RETURNS FOR EXAMPLE PROBLEM

<u>Type Contract</u>	<u>Capital Returns in Year</u>				<u>Total</u>
	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
Fixed Price	20,588	82,354	123,529	123,529	350,000
10.1% Discount	16,983	61,708	84,061	76,353	239,105
Cost Type	40,000	155,000	103,333	51,667	350,000
10.1% Discount	32,996	116,142	70,318	31,935	251,391

Example: Year 3

$$\text{Fixed Price: } \left(\frac{4000 \text{ units delivered in Year 3}}{17000 \text{ total units}} \right) (\$350,000 \text{ total capital})$$

$$= \$82,354$$

$$\text{Year 3 discount factor} = 0.7493$$

$$\text{Discounted fixed price capital return} = (\$82,354) (0.7493) = \$61,708$$

$$\text{Cost type: depreciation in Year 3} = \$155,000$$

$$\text{Discounted cost type} = (\$155,000) (0.7493) = \$116,142$$

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BIOGRAPHY

Vance K. Wilkinson (Van) is a project manager in the Gas Centrifuge Enrichment Program with Union Carbide Nuclear Division at Oak Ridge, Tennessee. Prior to his Union Carbide affiliation, Mr. Wilkinson spent over ten years in the military weapons development field. Preceding his development assignment, he spent a decade in USAF First Line Operational Units, including over 100 Vietnam combat missions.

Mr. Wilkinson is presently pursuing an Industrial Engineering doctorate at the University of Tennessee. He holds an M.E. in Industrial Engineering, an M.S. in Systems Engineering, and a B.S. in Aeronautical Engineering.

Mr. Wilkinson is a distinguished graduate of the Air Force Institute of Technology and was elected to Phi Kappa Phi and Tau Beta Pi. He holds numerous United States and foreign military decorations.

Van is a Registered Professional Engineer in the states of Ohio, Tennessee, and Texas. He is a senior member of AIEE and a member of ASME, NSPE, and TSPE.