ECONOMIC IMPACT OF INCREMENTAL POLLUTION CONTROL AT ASARCO'S TACOMA SMELTER

final report to

U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA

AND

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION X
SEATTLE, WASHINGTON

under

EPA CONTRACT NO. 68-02-1349
TASK ORDER NO. 10

ARTHUR D. LITTLE
CONTRACT NO. C-76072-86

JULY 1977

Arthur D. Little, Inc.

EPA 0398

ECONOMIC IMPACT OF INCREMENTAL POLLUTION CONTROL AT ASARCO'S TACOMA SMELTER

Final Report to

U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE, NORTH CAROLINA

and

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION X
SEATTLE, WASHINGTON

under

EPA CONTRACT NO. 68-02-1349 - TASK ORDER NO. 10

ARTHUR D. LITTLE CONTRACT NO. C-76072-86

JULY 1977

Arthur D. Little, Inc.

This report was furnished to the
U. S. Environmental Protection Agency
by Arthur D. Little, Inc., Cambridge,
Massachusetts, under Contract No. 68-
02-1349 - Task Order No. 10. Its
contents are reproduced herein as re-
ceived from the Contractor. The
opinions, findings and conclusions
expressed are those of the Contractor
and not necessarily those of the U. S.
Environmental Protection Agency

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

I. SUMMARY

A. INTRODUCTION

Asarco operates a copper smelter (and refinery) in Tacoma, Washington, which accounts for about 7% of the nation's copper smelting capacity. The Tacoma location has been used for smelting nonferrous ores and concentrates since about 1890. We understand that Tacoma started out initially as a lead smelter. Lead smelting was discontinued after about 20 years and Tacoma has been a copper smelter since then. Over the years, Tacoma has specialized in the smelting of copper concentrates high in impurity content and is currently the only U. S. smelter that produces byproduct arsenic trioxide.

The smelter installed a sulfuric acid plant in 1950, which recovered about 17% of the sulfur in the feed. In 1974, a liquid SO_2 plant was added. Both SO_2 recovery systems utilize converter gases and now recover a nominal 51% (average 48%) of the sulfur in the feed. A 563-foot stack is used to discharge the SO_2-containing streams. In addition, the smelter has curtailed production during adverse metereological conditions to decrease emissions (Supplementary Control System or SCS) and has employed professional metereologists for this purpose since 1969. Between 1971 and December, 1975, SCS was used successfully to meet National Ambient Air Quality Standards (NAAQS--three-hour and 24-hour standards), but there have been numerous violations of the short-term (5-minute, one-hour) Puget Sound Air Pollution Control Agency (PSAPCA) and Department of Ecology (DOE) standards. On four occasions in 1976, the NAAQS were violated.

Since 1970, PSAPCA has required Tacoma to limit its SO_2 emissions to 10% of the sulfur in the feed. Asarco operated from 1971 to 1975 under a variance from this regulation. In February, 1976, Asarco obtained another five-year variance from the emission standards. As a part of this variance, Asarco promised to increase the degree of particulate control at Tacoma.

B. PURPOSE, SCOPE AND APPROACH

This study is one of several studies commissioned by EPA/Region X, addressing the question of incremental pollution control at Tacoma. This study focuses on the economic impact. The two companion studies have already been completed by H. E. Cramer[1] and PEDCo-Environmental[2]. Of

---

[1] H. E. Cramer Co., Inc., "Assessment of the Air Quality Impact of SO_2 Emissions from the Asarco-Tacoma Smelter" (July, 1976), EPA 910/9-76-028.

[2] PEDCo-Environmental, "Evaluation of Sulfur Dioxide and Arsenic Control Techniques for the Asarco-Tacoma Smelter" (September, 1976), EPA 68-02-1321, Task Order No. 35.

these, the Cramer study used diffusion modeling to determine the degree of constant SO_2 emissions control required at Asarco-Tacoma to meet National as well as local ambient air quality standards. The PEDCo study determined the costs of various options that Asarco could use to increase the sulfur recovery rate above the design level of 51%. These costs were presented by PEDCo in mid-1978 dollars.

The approach used in this study is to assume that Asarco's decisions regarding Tacoma (to either spend the funds for incremental pollution control or to shut the plant down and exercise other options), will be based on rational microeconomic and financial principles. Thus, this analysis of investment decision-making under uncertainty essentially simulates the capital budgeting process at Asarco. It should be noted that such an approach cannot reflect accurately and completely the perceptions of risk and uncertainty of the decision-makers at Asarco. In real life, perceptions of risk and uncertainty can vary significantly from individual to individual and from firm to firm. Again, actions and reactions in real life may be more discontinuous than would be implied in theory.

An economic impact study of this type requires access to sensitive or confidential information at the plant level. On the other hand, since this is a public report, this confidential information can potentially be disseminated to a wide audience. Our approach has been to develop an understanding of all the major factors that can affect decision-making at Tacoma, such as pricing at other competitive smelters, raw material supply, transportation costs, revenues sources, production costs for mines, production costs at Tacoma, etc. In addition, we have developed an understanding of Asarco's accounting structure and cost allocation policies in order to assess Tacoma's past performance. Since the impact analysis period is from 1978 to 1985 (and beyond to 1995), the historical information can only be a guide in assessing the future. Thus, our impact analysis relies on estimates of revenues and costs in various categories (based on professional judgment) over the period from 1978-1995. The report uses constant 1978 dollars as a basis in order to be consistent with PEDCo costs.

The Tacoma smelter also faces incremental costs for meeting OSHA standards for control of inorganic arsenic. OSHA initially proposed a 0.004 mg As/m^3 standard. Subsequently, Arthur Young & Company[1] prepared an Inflationary Impact Statement for OSHA on the basis of three possible standards: 0.1, 0.05 and 0.004 mg As/m^3. Based on testimony received at the Hearings held in Washington, D.C., in September, 1976, the Department of Labor can presumably select one of these three standards

[1]Arthur Young & Company, "Inflationary Impact Statement--Inorganic Arsenic", Department of Labor, Occupational Health and Safety Administration (1976).

or some other standard. The costs for meeting these standards have been an issue of controversy since the Arthur Young & Company estimates are lower than others prepared on the same basis.[1] Our analysis includes OSHA costs, as estimated by Arthur Young & Company. OSHA costs would have a major impact on the continuation of the operations at the Tacoma plant. Potential costs for other possible standards such as ambient lead and arsenic and in-plant SO_2 and lead were not considered in the study.

Thus, this study is based on assessments (based on professional judgment) of:

- future raw material supply situation both with regard to impure and clean concentrates;
- the nature of smelting contracts and behavior of the major mines that supply Tacoma's concentrates viz. Duval, Lepanto and Northern Peru;
- the demand for and expected netbacks from Tacoma byproducts;
- the interrelationship between Tacoma and other Asarco plants;
- the future production costs at Tacoma;
- microeconomic analysis of the pricing behavior of Tacoma and the major mines that ship concentrates to Tacoma;
- financial analysis of the various control options and the pricing behavior of Tacoma;
- the influence of other standards, such as OSHA standards for Inorganic Arsenic which impact Tacoma in a significant fashion; and
- the sensitivity of the findings to alternative assumptions during which the baseline conditions (in a sense, "the most likely scenario") are relaxed.

C. FINDINGS

1. Incremental Pollution Control Costs

Various combinations of incremental SO_2 control, particulate control and OSHA regulations for inorganic arsenic were examined to define a range of incremental costs at Tacoma. These options and the associated capital investment and O&M costs are shown in Table I-1. For analytical purposes,

---

[1]See Chapter V.

TABLE I-1

INCREMENTAL COSTS AT ASARCO-TACOMA UNDER ALTERNATIVE CONTROL OPTIONS
(millions of 1978 dollars)

Control Options	WITHOUT OSHA		WITH OSHA	
	Capital Investment (Total)	Operating and Maintenance Costs (per year)	Capital Investment (Total)	Operating and Maintenance Costs (per year)
			36.0	4.8
OPTION 1				
Electric furnace smelting; acid plant consolidation	55.9	5.8	-	-
Particulate control	5.6	0.8	-	-
TOTAL	61.5	6.6	97.5	11.4
OPTION 2				
Roaster gas enrichment; acid plant consolidation	34.9	5.5	-	-
Particulate control	5.6	0.8	-	-
TOTAL	40.5	6.3	76.5	11.1
OPTION 3				
Improve existing acid plant	1.5	0.2	-	-
Roaster gas enrichment; acid plant consolidation	34.9	5.5	-	-
Particulate control	5.6	0.8	-	-
TOTAL	42.0	6.5	78.0	11.3
OPTION 4				
Improve existing acid plant	1.5	0.2	-	-
Particulate control	5.6	0.8	-	-
TOTAL	7.1	1.0	43.1	5.8

Source: Based on Table V-5.

these options function as surrogates for other control options with similar capital cost and O&M cost requirements.

2. Baseline Conditions

Asarco-Tacoma is a copper smelter/refiner deriving the bulk of its revenue by providing smelting/refining services, essentially on a toll basis. Its revenues from these toll services are supplemented by additional revenues from the sale of byproducts. Under the baseline conditions, we have assumed that the toll smelting/refining revenues will continue to reflect a "contractual pricing" approach on the part of Tacoma, which has been commonly used in the copper industry for years, both within the U. S. and internationally.

Baseline conditions reflect the basic outlook that domestic smelter capacity growth is effectively constrained through 1983 at the earliest, but that sufficient Japanese smelter capacity will be available to absorb "overflow" U. S. concentrates and that a new Philippines smelter, scheduled to commence operations in 1981, would provide potential competition to Tacoma in terms of the suppliers of dirty concentrates.

The assumed toll rate of 22.7¢/lb for baseline analysis is broadly congruent with long-run copper floor prices at around 80¢/lb, such that, under these copper price and toll conditions, all of Tacoma's suppliers would be expected to continue remaining in business as they would cover their long-run costs.

The baseline conditions assume annual production of 100,000 short tons of refined copper, all derived from Tacoma-produced blister. Tacoma's feed sources consist of clean concentrates (i.e., Duval and other Southwestern mines), impure concentrates (i.e., Lepanto, Northern Peru and East Helena), and scrap and precipitates. Tacoma requires a mix of dirty and clean feedstocks in order to control the impurity content of the final product.

The market that Tacoma faces for its smelting/refining services has the following characteristics: The suppliers of clean concentrates (Duval and other Southwestern producers) would switch to Japan if Tacoma's price for this service exceeded the price offered by the Japanese smelters on a freight-equalized basis. This condition holds both in the short-run and the long-run. In addition, there are other possible options in the long-run such as the construction of a new facility based on either pyrometallurgical or hydrometallurgical techniques. Since Tacoma needs clean concentrates to dilute the impurities, the loss of these clean concentrates for any reason would force a Tacoma shutdown even if additional impure concentrates were available.

The suppliers of impure concentrates have perfectly inelastic demand until 1981, when the new Philippines smelter is scheduled to start operations and are in the least favorable position in terms of a higher toll charge by Tacoma in the short-term. Tacoma's ability to arbitrarily increase the price paid by these mines in the short-term is limited by the absolute level of copper prices and the terms now operative in existing contracts, which permit only a "pass-on" of increased cost in certain categories. After 1980, the Philippines smelter would be in operation and Lepanto (and perhaps Northern Peru) would have an alternate outlet. Lepanto could consider increasing its mine output to continue supplying Tacoma under certain long-run copper price conditions, and depending upon Tacoma's pricing behavior vis-á-vis Lepanto, both before and after 1981.

The suppliers of scrap and precipitates have perfectly elastic demand for Tacoma's services, since they have numerous alternative outlets. Any price increase to these suppliers would trigger a switch of these suppliers away from Tacoma.

The U. S. copper industry is expected to face smelter capacity constraints until about 1983-1985, which result mainly from the way in which EPA regulations (the Tall Stack Guidelines and the New Source Performance Standards) prevent small increments of capacity at existing smelters. As a result of this constraint, the copper prices in the U. S. would be higher compared to the prices expected in the absence of these regulations.

3. Methodology

The methodological approach used in this report consists of an integrated microeconomic/financial analysis framework to determine (on rational financial/economic grounds) whether the management of Asarco-Tacoma would be expected to invest in additional control and continue production at Tacoma or decide to discontinue operations, and conduct an orderly plant shutdown. The financial analyses were performed within an internally consistent microeconomic framework defining revenue streams at Tacoma, by taking into consideration several hypothesized copper prices, each supplier's costs of production, Tacoma's potential competition in terms of the availability of smelting/refining services provided by others and their relative freight-equalized costs. Microeconomic analysis thus helped define the degree of freedom available to, and the constraints operating upon, each one of Tacoma's suppliers over time, under different sets of long-run copper prices.

The financial analysis, which focused on the net present value of cash flows at Tacoma, attempted to simulate Asarco decision-making with respect to investment and operating strategies at Tacoma. Modern financial theory and managerial economics characterize this type of problem as one of investment decision-making under uncertainty. In effect, this approach simulates the capital budgeting process at Asarco.

The techniques of capital budgeting employ the following concepts:

- Time value of money, i.e., a unit of money received today is worth more than money received at a later date.

- In the absence of constraints on external financing, alternative courses of action can be compared by discounting future cash flows to the present to obtain the Net Present Value (NPV) of each alternative course of action using an appropriate discount rate. All else equal, the preferred course of action is the one with the highest Net Present Value.

- The discount rate used in the estimation of Net Present Value is one that appropriately compensates the investor for the risk incurred and that this rate is higher than that for a risk-free investment such as a U. S. Treasury obligation. In our view, a 10% constant dollar discount rate would be a minimum for Asarco and a 15% discount rate would be a representative discount rate in the present context.

4. Findings Under Baseline Conditions

The baseline conditions assume a Tacoma smelter/refinery capacity of 100,000 tons/year based on 78,000 tons/year from sulfur-bearing materials, i.e. clean concentrates from Duval and other Southwestern mines; impure concentrates from Lepanto; Northern Peru and East Helena byproducts; and 22,000 tons/year of scrap and precipitates. Furthermore, they assume that Tacoma would continue its normal "contract pricing" approach for pricing its toll smelting and refining services.

In short, the baseline conditions best reflect normal pricing behavior and the normal, historical relationship between a toll smelter/refinery and its suppliers. It is consistent with long-run considerations which typically govern the decisions and interrelationships of the nonferrous metals companies.

The impact analysis methodology described above was used to analyse the five incremental pollution control options described in Table I-1 and the remaining alternative; namely, the shutdown of Tacoma operations. Table I-2 summarizes the net present values of after-tax cash flows at 10% and 15% discount rates for these alternatives. The table indicates that Option 4.1B (minimum control, no OSHA) is the only control option with a significant positive net present value. However, when compared to shutdown, it cannot be stated unambiguously that Option 4.1B would be preferred over shutdown. All other options have relatively large negative net present values and suggest (without much ambiguity) that a shutdown decision would be preferred under baseline conditions.

5. Sensitivity Analysis

The sensitivity analysis reexamines the conclusions reached under the baseline assumptions under conditions when the baseline conditions are progressively relaxed. The following relaxations of the baseline conditions were performed in order to examine the "feasibility space" or conditions under which the specific pollution control options would be preferred over the shutdown of Tacoma. The sensitivity analysis results are summarized in Table I-3.

TABLE I-2

ESTIMATED NET PRESENT VALUES: POLLUTION CONTROL SUPERIMPOSED ON BASELINE CONDITIONS[a]
(in millions of 1978 dollars)

Options Considered	Net Present Value at Discount Rate of 10%	15%
4.1B (Minimum control, no OSHA)	+6	+4
4.2B (Minimum control, with OSHA)	-26 to -40	-21 to -31
3.1B (Intermediate; delay, no OSHA)	-21 to -36	-16 to -24
3.2B (Intermediate; delay; with OSHA)	Min. - 41	Min. - 34
1.1B (Maximum control; no OSHA)	Min. - 32	Min. - 26
1.2B (Maximum control, with OSHA)	Min. - 60	Min. - 50
Tacoma Shutdown	← +17 to +20 →	

Notes: See Tables V-20 and V-21

TABLE I-3

SUMMARY OF SENSITIVITY ANALYSIS RESULTS

Option	Baseline Conditions	Discriminatory Monopolistic Pricing Under Long Run Copper Price at (cents/lb)[a] 80	85	90	100	Presence of Other Regulatory Costs[b]	Higher Transportation Costs[b]	Lower Smelter/ Refinery Output[b]	Lower Variable Cost/Higher Profit[b]	Historical Cash Flow[b]	Lower Capital Investment[b]
4.1B - Minimum Control, no OSHA	Y	Y	Y	Y	Y	M	Y	Y	Y	Y	Y
4.2B - Minimum Control, with OSHA	N	M	M	Y	Y	N	N	N	N	N	N
3.1B - Intermediate; Delay; no OSHA	N	M	Y	Y	Y	N	N	N	N	N	N
3.2B - Intermediate; Delay; with OSHA	N	N	N	N	M	N	N	N	N	N	N
1.1B - Maximum Control, no OSHA	N	N	N	M	M	N	N	N	N	N	N
1.2B - Maximum Control, with OSHA	N	N	N	N	N	N	N	N	N	N	N

Notes: Y = Yes--microeconomic/financial analysis indicates that a given control option is feasible and preferred over shutdown.
N = No--microeconomic/financial analysis indicates that a given control option is not feasible.
M = Maybe--microeconomic/financial analysis indicates that a given control option is barely or marginally feasible.

a. Version A revenue stream (i.e., Lepanto falls out after 1980 and is replaced by other domestic suppliers of clean concentrates.
b. These reflect modifications of base conditions reported in the first column.

a. Discriminatory Monopolistic Pricing

It might be argued that if domestic copper prices are at a level where all of Tacoma's suppliers stay open, it is possible for Tacoma to pursue a discriminatory monopolistic pricing strategy to maximize its revenues. Under this strategy, as domestic copper prices rise for any reason (e.g., a bottleneck in domestic smelter capacity), Tacoma would push each supplier to the limit to extract maximum smelting/refining revenues without losing the suppliers either via the mines shutting down or via mines switching to alternative sources of toll smelting/refining services.

If progressively higher long-run copper prices are hypothesized, along with a discriminatory monopolistic pricing strategy on the part of Tacoma, the pollution control options become increasingly feasible. This is because, at higher copper prices, revenues during earlier years (which are important in any discounted cash flow analysis) become larger, contributing to improved Net Present Value results.

Thus, at a level copper price of 85¢/lb (1978 basis), Option 3.1B (intermediate control; no delay; no OSHA) becomes viable. Similarly, at a copper price of $1.00, Option 4.2B (minimum control, with OSHA) becomes unambiguously viable in addition to Option 3.1B.

While discriminatory monopolistic pricing represents a theoretically correct mode for Tacoma to maximize its revenues, it represents a sharp reversal of the manner in which such services have been priced in the past and might also require Tacoma to use a strategm such as force majeure to break existing contracts. Given that individual smelters/refiners have no influence on copper prices, they have not followed such a strategy in the past (i.e., they have been risk-averse) not knowing beforehand what the copper price would be over the next contract cycle.

b. Other Regulations and Associated Compliance Costs

Tacoma faces other possible regulations and compliance costs such as OSHA in-plant lead and SO_2 standards and EPA ambient lead and arsenic standards. Thus, while the potential impact of incremental SO_2 control and OSHA standards can be slightly altered by assuming an extended compliance schedule, these other regulations and associated costs and uncertainty, could affect Asarco's perception of risk and of the future viability of Tacoma. A perception of high risk would tend to decrease the viability of any proposed incremental control option.

c. Transportation Costs and "Distress" Payment

The analysis assumed that Duval and the Southwestern mines paid the Japanese smelters an extra "distress payment" to persuade the Japanese to accept their concentrates. The assumed distress payment is about four times the normal profit from smelting and refining. For this reason (and the fact that these mines would be shipping to Japan on a long-term basis), it can be argued that a lower distress payment is more appropriate. The sensitivity analysis under different distress payments and with an assumed higher level of transportation costs does not alter the conclusions reached under baseline conditions.

d. Alternative Cash Flows

Several alternative cash flows were hypothesized and their influence on the baseline conclusions was examined. A cash flow different from the baseline can be hypothesized on the basis of: a lower production rate of 95,000 tons/year; an arbitrary decrease in variable costs resulting in a pre-tax profit that is 10% of sales revenue; accelerated vs. straight-line depreciation; different levels of on-going replacement investment, etc. None of these variations alter the conclusions reached under the baseline conditions.

One might argue that since profits or net earnings are usually obtained as the difference between two relatively large numbers--revenues and costs--their magnitude is sensitive to errors in estimation of either revenues or costs or both. An independent check of the profit and cash flow used in the baseline analysis is a comparison with Tacoma's historical performance. Over the ten-year period (1965-1974), Tacoma's average pre-tax net earnings were $1.85 million/year and gross earnings were $3.34 million/year. If this average is adjusted for inflation and converted to 1978 dollars, it is about $2.8 million, significantly below the $3.3 million pre-tax profit assumed under the baseline conditions.

The difference between the Net Present Value associated with Option 4.2B (minimum SO_2 control, with OSHA) and the option of closing Tacoma is about $40 million. Thus, for Option 4.2B to be viable, additional NPV of $40 million would be required to bring this option on par with shut-down, looking only at the strict financial criterion of comparing NPV's and treating the alternatives as being of comparable risk. An increase in annual cash flow of $5-6 million/year at 10% and 15% discount rates, respectively, is necessary for this to occur. Alternately, revenues have to increase by about $10-12 million/year--equivalent to an increase in toll smelting and refining charges of 7-8¢/lb copper. Given that the estimated baseline profits are already higher than the average historical performance, their reestimation under different (but reasonable) assumptions is not likely to show the type of cash flow which will alter the conclusions reached under baseline conditions. This increased cash flow is possible, however, under discriminatory monopolistic pricing, as discussed earlier.

e. Other Factors

Variations in capital investment and in time-phasing of the pollution control expenditures do not have an effect significant enough to alter any of the conclusions under baseline conditions.

6. Limitations of Analysis

In this report, we have assessed the economic impact of incremental pollution control expenditures on Tacoma under hypothesized base conditions. We have further performed a series of sensitivity analyses to examine the sensitivity of these conclusions to progressive relaxation of these base conditions. This has enabled us to explore the impact analysis problem under a reasonably wide range or combinations of conditions, to check whether the final conclusions remain the same or are to be modified as these base conditions are relaxed.

Generally speaking, our baseline and sensitivity analysis leads us to believe that the conclusions reported are fairly "robust" (i.e., strong, invariant, not very sensitive) over a wide margin of variability in the magnitude of the numbers used in this report. Thus, our conclusions will not be altered significantly if somewhat different sets of numerical estimates are used. A different set of such numerical estimates could be derived by other analysts by using more precise historical data and/or by using their professional judgment. We believe it is unlikely for such numerical estimates to fall outside the range used in the sensitivity analysis and, even if they did, for them to be in a direction such that the basic conclusions are altered. For these reasons, we believe that additional historical data are not likely to have a significant effect on the conclusions.

While the sensitivity analysis helps define a "feasibility space" over which certain options are either feasible or not feasible, certain limitations remain. These limitations generally fall into five broad categories which are not necessarily mutually exclusive: (1) variables or factors omitted from consideration; (2) the reliability of the data used and the correctness of their extrapolation over the impact period of 1978-1995; (3) validity of the methodological approach; (4) reasonableness of the future "state(s) of the world" hypothesized for analysis; and (5) correctness of the postulated decision-making behavior on the part of Asarco.

There exist major uncertainties in the future with respect to other potential environmental regulations and associated compliance costs at Tacoma. These relate not only to costs for incremental SO_2 control and for OSHA-inorganic arsenic standards which are treated explicitly in this report, but also to other potential costs (for ambient lead, arsenic, in-plant SO_2 and other standards) which could also be incurred over the impact analysis period. This factor increases the uncertainties at Tacoma. Our impact results are understated to the extent that these costs are not explicitly considered.

Our analysis over the period 1978-1995 relies on numerous estimates and projections prepared (by us or by others) on the basis of professional judgment using available information as a guide. As noted already, the conclusions are "robust" and quite insensitive to these projected values. The conclusions change only under the twin assumptions of high, long-run copper prices starting in 1978 and of Tacoma's willingness based on this expectation, to push all suppliers to the limit by practicing discriminatory monopolistic pricing.

The methodological approach used in our analysis, relying on integrated microeconomic and financial analysis principles and practice, is predicated upon rational economic behavior. This may involve at least two types of shortcomings. In the first instance, actions or reactions in real life may be more discontinuous than would be implied by theory. Moreover, certain "intangible" factors may be completely ignored by the underlying theory utilized. For example, before embarking on a course of discriminatory monopolistic pricing, Asarco may have to weigh such intangibles as possible loss of "goodwill." While "goodwill" is intangible in the sense that it is difficult to quantify, it might be an important issue to Asarco given the fact that a majority of new projects in the mineral industry are joint ventures and goodwill is important for the continuation of this practice. Similarly, Asarco may not want to antagonize the Government of Peru about Northern Peru, since Asarco has a much larger equity investment in the Southern Peru Corporation of approximately $160 million.

It is not possible to define the future "state(s) of the world" (1978-1995) in a precise manner. A single unique set of future conditions, including copper prices, can be neither defined nor, of course, guaranteed for such impact analysis. There are many participants in the present analysis, each having a possibly different set of future expectations (e.g., on copper prices), different set of alternatives open to them, and different perceptions of risk than may be imputed to them in the analysis here. The participants are assumed to behave in certain ways, based on theory, which may not, in reality, occur, not because of any deficiency in theory, but because real life is typically more uncertain and therefore too complicated to be fully predicted through microeconomic or financial analysis. Such factors include the "intangible" factors mentioned above; legal risks that might be taken by Asarco-Tacoma in pursuing a discriminatory monopolistic pricing strategy; the possibility that Lepanto, rather than paying high toll charges over the period 1978-1980 as Tacoma's monopolistic pricing behavior would require, might instead produce and stockpile its concentrates until the new Philippines smelter opens, and so on. These points, taken together, cumulatively indicate that the revenue streams estimated for Tacoma over the period 1978-1995 under Tacoma's hypothesized discriminatory monopolistic pricing behavior represent upper-bounds under each assumed long-run copper price level.

Finally, it should be noted, that any analysis by a third party cannot capture in complete detail the full range of decision options of Asarco, Duval, other Southwestern mines, Japanese smelters, Lepanto, Northern Peru, and the Peruvian Government, etc. Such an analysis cannot completely capture their perceptions of risk and uncertainty, subjective and intangible factors such as goodwill, matters relating to litigation or threat of litigation from suppliers, etc. However, while all the details of the thinking of interested parties in this issue have not been captured, we believe that our analytical approach represents a reasonable approximation of the central logic of the major participants (i.e., Asarco's) decision-making relating to the Tacoma smelter and refinery.

II. OVERVIEW OF THE U. S. COPPER INDUSTRY AND DESCRIPTION OF ASARCO'S OPERATIONS

A. INTRODUCTION

This chapter provides an overview of the U. S. copper industry and a description of Asarco's operations. The material presented in this chapter is designed to give the reader the necessary background information and perspective in which to place Asarco's Tacoma operations described in detail in the next chapter.

The United States, the leading producer and consumer of copper in the world accounting roughly for one-fifth of total world refined copper production, consumption and reserves, has in the past been virtually self-sufficient in copper.

Production of copper from primary (virgin) sources, based mainly on the exploitation of sulfide mineral deposits, involves four principal stages of production: mining, beneficiation (milling), smelting and refining. U. S. mine production of copper reached 1.7 million short tons (metal content) in 1973, a peak year. U. S. smelter and refinery capacity is about 1.9 million short tons and 2.7 million short tons of annual production, respectively.

Asarco, a major world producer of nonferrous metals with operations and business interests both in the United States and abroad (e.g., Canada, Mexico, Peru, Australia) is an important producer of copper domestically, operating four open-pit mines, three smelters to process the copper concentrates from the mines of Asarco and others, and two refineries. Asarco represents about 5% of total U. S. mine output, 20% of total U. S. smelter capacity and 25% of total U. S. primary refinery capacity.

In recent years, the U. S. copper industry, including Asarco, has experienced modest growth in sales, low return on invested capital, eroding profit margins and higher debt, reflecting the combined pressure of inflation, higher cost of capital, increased capital requirements for environmental control and a deep and prolonged economic recession.

B. OVERVIEW OF THE U. S. COPPER INDUSTRY

1. Supply

The United States is the leading producer and consumer of copper in the world, accounting roughly for one-fifth of total world refined copper production, consumption and reserves. Except for certain periods in the past coinciding with military developments or unusual "demand crunch" periods, the United States has been nearly self-sufficient in copper.

Production of refined copper in the United States from all sources is detailed in Table II-1 for 1974, 1975 and 1976. As shown here, production of domestically mined copper accounts for a major share of the total U.S. refined copper supply stream. It should also be noted that refined copper from scrap, produced both by refineries and by "secondary plants" (i.e., numerous small smelters of scrap copper), makes an important contribution to total U.S. refined copper supply. Unrefined copper from new and old scrap, used directly, represents, on its own right, a significant source of copper supply.

Most of the domestically mined copper is produced in five western states--Arizona, Utah, New Mexico, Montana and Nevada. Over 80 percent of total U.S. mine production is located in Arizona, Utah and New Mexico taken together. Arizona alone accounts for well over half the total U.S. mine production of recoverable copper (about 63% in 1976).

The production of copper from primary (virgin) sources is based mainly on the exploitation of sulfide mineral deposits, and involves four stages of processing:

- mining--where ore containing approximately 0.4-2% copper is mined;

- beneficiation (or milling)--where the copper-containing minerals are separated from waste rock to produce a concentrate containing about 25% copper;

- smelting--where concentrates that contain about 25 percent copper are melted and reacted to produce 98% pure "blister" copper; and

- refining--where blister copper is refined electrolytically to produce 99.9% pure cathode copper. Some of the new hydrometallurgical processes combine the functions performed by smelting and refining. Subsequently, cathode copper is melted and cast into various shapes for fabrication.

About 98% of the domestic mine production of copper comes from ores mined primarily for their copper content, the remainder is recovered from complex or mixed base-metal ores. The copper ores also are the source of significant quantities of byproducts and coproducts such as gold, silver, molybdenum, nickel, platinum, selenium, tellurium,

TABLE II-1

PRODUCTION OF REFINED COPPER IN THE UNITED STATES, BY SOURCE, 1974-1976[a]

(thousands of short tons)

SOURCE	1974			1975			1976		
	TOTAL	Produced by:		TOTAL	Produced by:		TOTAL	Produced by:	
		Refineries	Secondary Plants[d]		Refineries	Secondary Plants[e]		Refineries	Secondary Plants[e]
TOTAL (primary and secondary)	2,151,566	2,067,177	84,389	1,787,864	1,714,258	73,606	1,911,668	1,825,874	85,794
Primary (new) refined copper produced in the United States	1,654,658	1,654,658	-	1,443,378	1,443,378	-	1,537,188	1,537,188	-
from domestic ores, as reported by refineries[b]	1,420,905	1,420,905	-	1,268,189	1,286,189	-	1,420,603	1,420,603	-
from foreign ores, matte, etc., as reported in refineries[b]	233,753	233,753	-	157,189	157,189	-	116,585	116,585	-
Secondary refined copper produced in the United States[c]	496,908	412,519	84,389	344,486	270,880	73,606	374,480	288,686	85,794
from new scrap	NA	229,328	NA	NA	139,230	NA	NA	144,215	NA
from old scrap	NA	183,191	NA	NA	131,650	NA	NA	144,471	NA

Notes and Sources:
a. U. S. Bureau of Mines, Mineral Industry Surveys, "Copper in 1976" (April 15, 1977), p. 4.
b. The separation of refined copper into metal of domestic and foreign origin is only approximate, as accurate separation is not possible at this stage of processing.
c. Includes copper reported from foreign scrap.
d. U. S. Bureau of Mines, 1974 Minerals Yearbook, Copper, Preprint, p. 28.
e. U. S. Bureau of Mines, Mineral Industry Surveys, "Copper in December 1976" (March 10, 1977). p. 3.
NA: Not available on a consistent basis from public sources.

palladium, arsenic, rhenium, iron, lead, zinc, and sulfur. Lead, molybdenum, iron, and zinc minerals are separated from copper minerals by selective flotation. Gold, silver, nickel, platinum, palladium, selenium, and tellurium are recovered from anode sludges at electrolytic copper refineries. Arsenic and sulfur are extracted during copper smelting, and rhenium is obtained in the processing of molybdenum concentrates recovered as a coproduct in the treatment of some copper ores.

To minimize transportation costs, mills are almost always located close to the mines. The value of the concentrates is high enough to allow some flexibility in smelter location. Still, most smelters are located near the mills which supply them or on tide water or rail head in order to receive concentrates from distant mills. Refineries can be located anywhere between smelters and fabricators, since the transportation costs for blister and refined copper are about the same.

The domestic copper industry can be segmented into "primary" and "secondary" sectors, for analytical purposes, on the basis of the pricing behavior of the firms on the sellers' side. By this criterion, the primary sector consists of firms which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap) on the basis of a commonly-followed domestic producers' price. Firms in the secondary sector, on the other hand, are those which sell their copper output regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether processed from mined copper--from domestic or foreign source--or refined from scrap) on the basis of one of several "outside market" prices.

The primary sector consists of firms vertically integrated to different degrees from mining to refining and beyond into fabrication. These firms include principally, the following: Anaconda/ARCO, Asarco, Cities Service, Copper Range, Cyprus, Duval, Hecla, Inspiration, Kennecott, Magma, Phelps Dodge and Ranchers Exploration. These twelve firms market their own copper. Several of these sellers do not have their own smelting or refining facilities and have their raw materials treated by others.

Several of the producers participate either directly or through subsidiaries in all five stages of production: mining, milling, smelting, refining and fabrication. The productive capacities, however, are not always matched between the different stages of production. Kennecott, the largest U. S. producer, is vertically integrated from mining through refining and, to a very small extent, further integrated downstream into fabricating through its wholly owned subsidiary, Chase Brass and Copper, which reportedly purchased 25% of its copper requirements in 1976 from Kennecott (constituting about 6.6% of Kennecott's copper sales in that year). Anaconda participates in fabrication through Anaconda American Brass and Anaconda Wire and Cable. These subsidiaries consume more copper than is produced by Anadonda. Phelps Dodge produces wire, wire rod and copper tube. These fabricating facilities consume about 30% more copper than the primary production of Phelps Dodge. Similarly, Cities Service owns New Haven Copper and Chester Cable; Copper Range owns Hussey Metals; Cyprus owns Cyprus Wire and Cable and El Paso Natural Gas (participant with Hecla

Mining in the Lakeshore project) owns Narragansett Wire. While Asarco does not own fabricating capacity directly, it owns 33% of Revere.

Other producers are vertically integrated from mining through refining. These include producers of refined metal using smelting techniques (Magma/Newmont); using hydrometallurgical techniques (Ranchers) or both (Inspiration). Magma and Inspiration also produce semifabricated shapes.

The other producers do not participate fully in all stages of production. While Cities Service in Tennessee is integrated through smelting, its more significant production in Arizona is treated by Inspiration. Cyprus and Duval, except for experimental hydrometallurgical plants, use custom/toll smelters and refineries. Cyprus uses Phelps Dodge and Magma, and Duval uses Asarco. Similarly, Amax does not possess primary smelting and refining capacity. Amax's smelter and refinery in New Jersey treats mainly secondary materials. Its primary production is from Anamax, operated under equal partnership with Anaconda, by hydrometallurgical means. In addition, there are smaller independent mining firms, such as UV Industries, Earth Resources, Hecla Mining, McAlester Fuel, Federal Resources, Eagle-Picher, Keystone Wallace Resources, and Micro Copper, who use custom or toll smelting and refining services. The major custom and toll smelters and refiners are Asarco, Phelps Dodge, Inspiration and Anaconda. Others such as Magma process only minimal quantities.

Detailed information on mine production of recoverable copper in the United States, as well as on U. S. smelter and refinery capacity, is presented in Tables II-2, -3, and -4. In 1974, four firms--Kennecott, Phelps Dodge, Anaconda, and Newmont--accounted for 64% of total U. S. mine production. Eight firms, including these four plus Duval, Cyprus, Asarco and Copper Range, accounted for 88% of the total. Seven firms--Asarco, Kennecott, Phelps Dodge, Magma, Anaconda, Inspiration, and Copper Range--together represent virtually all of total U. S. smelter and primary refinery capacity.

Asarco, taken by itself, represents about 5% of total U. S. mine output, 20% of total U. S. smelter capacity and 25% of total U. S. primary refinery capacity.

2. Demand

Copper is a metal of key importance, both because of its highly desirable properties (e.g., high electrical and thermal conductivity, corrosion resistance, ductility and malleability durability, low melting point and high strength) and because of its diversity of uses. Copper has a wide range of uses in today's modern industrial economy, in pure or alloyed form, including such diverse products as plumbing fixtures, ship propellers, electrical wire and car radiators. While aluminum and other materials are substitutable for copper and alloys in many electrical structural and decorative applications, in still many other uses copper is the preferred and largely nonsubstitutable resource. Copper consumption trends in the United States since 1950 are shown in Table II-5. It can be seen that refined copper accounts for a large

TABLE II-2

MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES, 1973 and 1974[a]

Company and Mine	Location	Mine Type	Amount (Short tons) 1973	Amount (Short tons) 1974	Composition (%)[b] 1973	Composition (%)[b] 1974
Kennecott Copper Corporation			471,721	402,213	27.46	25.19
Chino	New Mexico	OP	67,836	60,557	3.95	3.79
Nevada	Arizona	OP	50,012	37,562	2.91	2.35
Ray Mines	Arizona	OP	98,908	74,764	5.76	4.68
Utah	Utah	OP	254,965	229,330	14.84	14.36
Phelps Dodge Corporation			319,358	280,211	18.59	17.55
Morenci	Arizona	OP	119,535	112,790	6.96	7.06
Tyrone	New Mexico	OP	104,011	97,030	6.05	6.08
Ajo (New Cornelia)	Arizona	OP	53,797	43,501	3.13	2.72
Bisbee (Copper Queen0	Arizona					
Lavender Pit		OP	19,387	11,833	1.13	0.74
Underground Mines		UG	22,628	15,057	1.32	0.94
The Anaconda Company			200,454	190,059	11.67	11.90
Twin Buttes (Anamax Mining Co., under equal partnership with Amax Inc.)	Arizona	OP	36,824[c]	20,071[c]	2.14	1.26
Berkeley Pit	Montana	OP	104,474	98,889	6.08	6.19
Anaconda Vein Mines (Leonard, Load Haul Dump, Mountain Con, Steward Mines)	Montana	UG	21,674	17,454	1.26	1.09
Continental East Pit	Montana	OP	1,647	15,676	0.01	0.98
Yerington	Nevada	OP	35,835	37,969	2.09	2.38
Newmont Mining Corporation			160,381	151,826	9.34	9.51
Magma Copper Co.[d]						
San Manuel	Arizona	UG	22,474	29,437	1.31	1.84
Superior	Arizona	UG	135,789	120,208	7.90	7.53
Idarado Mining Co.[e]						
Idarado Mine	Colorado	UG	2,118	2,181	0.12	0.14
Duval Corporation (Subsidiary of Pennzoil Co.)			131,214	131,843	7.64	8.26
Battle Mountain, Esperanza, Mineral Park	Nevada, Arizona	OP	55,619	52,249	3.24	3.27
Sierrita	Arizona	OP	75,595	79,594	4.40	4.98
Cyprus Mines Corporation			110,390	103,353	6.43	6.47
Cyprus Pima Mining Co., Pima Mine	Arizona	OP	88,140	81,889	5.13	5.13
Cyprus Bagdad Copper Company, Bagdad Mine	Arizona	OP	19,152	18,379	1.12	1.15
Cyprus Bruce Copper and Zinc Co.	Arizona	UG	3,098	3,085	0.18	0.19
Asarco Incorporated			73,100	79,200	4.26	4.96
Mission	Arizona	OP	46,600	40,300	2.71	2.52
Silver Bell	Arizona	OP	23,800	23,500	1.39	1.47
San Xavier	Arizona	OP	2,700	5,900	0.16	0.37
Sacaton	Arizona	OP	-	9,500	-	0.59
White Pine Copper Company (Subsidiary of Copper Range Co.)						
White Pine	Michigan	UG	78,506	66,898	4.57	4.19
Inspiration Consolidated Copper Company			65,196	61,238	3.80	3.83
Christmas	Arizona	OP	9,508	6,698	0.55	0.42
Inspiration (Thornton, Live Oak, Red Hill)	Arizona	OP	51,332	49,700	2.99	3.11
Ox Hide	Arizona	OP	4,356	4,840	0.25	0.30
Cities Service Company			33,280	33,855	1.94	2.12
Copperhill	Tennessee	UG	4,025	970	0.24	0.06
Miami (Copper Cities, Diamond H, Pinto VAlley)	Arizona	OP	29,255	32,885	1.70	2.06
Amax (Anamax Mining Co., under equal partnership with Anaconda)						
Twin Buttes	Arizona	OP	36,824[c]	20,071[c]	2.14	1.26
UV Industries, Incorporated						
Bayard Operations	New Mexico	OP	24,240	24,167	1.41	1.51
SUBTOTAL (of ABOVE COMPANIES)			1,704,664	1,544,934	99.23	96.74
OTHERS (Calculated Residually)[f]			13,276	52,068	0.73	3.26
TOTAL[g]			1,717,940	1,597,002	100.00	100.00

NOTES AND SOURCES: ACCOMPANYING TABLE II-2

a. Individual company data have been obtained from the 1973 and 1974 corporate annual reports and from American Bureau of Metal Statistics, Inc. (ABMS), Nonferrous Metal Data 1974 and 1975.
b. Sum of the components may slightly differ from the totals given due to rounding-off.
c. One-half of total Anamax production.
d. 100.0% owned by Newmont Mining Corporation.
e. 80.1% owned by Newmont Mining Corporation.
f. The "Other" category was calculated as the residual of the total less the subtotal for the individual companies reported above. This category includes, for example, Rancher's Exploration and Development Corporation, Earth Resources Company, El Paso Natural Gas Company, Hecla Mining Company, McAlester Fuel Company, Federal Resources Corporation, Eagle-Picher Industries Incorporated, Keystone Wallace Resources, Micro Copper Corporation and others.
g. The total is obtained from U. S. Bureau of Mines, Mineral Industry Surveys, "Copper in 1974" (April 8, 1975) for 1973 data (p. 3) and "Copper in 1975" (March 26, 1976) for 1974 data (p. 3).

TABLE II-3

COPPER SMELTERS IN THE UNITED STATES AT THE END OF 1975

Company	Location	Annual Capacity: Short tons of material[a]	Annual Capacity: Short tons of product[b]
Asarco, Inc.	El Paso, Texas	576,000	100,000
Asarco, Inc.	Hayden, Arizona	960,000	180,000
Asarco, Inc.	Tacoma, Washington	600,000	100,000
The Anaconda Company	Anaconda, Montana	750,000	198,000[c]
Cities Service Company, Copperhill Operations	Copperhill, Tennessee	75,000	16,000
Inspiration Consolidated Copper Company	Miami, Arizona	450,000	150,000
Magma Copper Company (subsidiary of Newmont Copper Co.), San Manuel Division	San Manuel, Arizona	800,000	200,000
Kennecott Copper Corporation			
Nevada Mines Division	McGill, Nevada	400,000	78,000
Chino Mines Division	Hurley, New Mexico	400,000	80,000
Ray Mines Division	Hayden, Arizona	420,000	80,000
Utah Copper Division	Garfield, Utah	1,000,000	280,000[d]
Phelps Dodge Corporation[e]			
Douglas Smelter	Douglas, Arizona	700,000	90,000
Morenci Branch	Morenci, Arizona	900,000	196,000
New Cornelia Branch	Ajo, Arizona	250,000	77,000
SUBTOTAL		8,281,000	1,825,000
White Pine Copper Co. (subsidiary of Copper Range Company)		NA	85,000
TOTAL		-	1,910,000

NOTES AND SOURCES: ACCOMPANYING TABLE II-3

a. American Bureau of Metal Statistics, Inc. (ABMS), Nonferrous Metal Data 1975, p. 29. Figures given represent short tons of "change" (i.e., material intake or "feed" for processing).

b. Estimated based on individual company annual reports, 10-K forms, telephone conversations with individual company/plant representatives, and data given in Engineering and Mining Journal (E/MJ), 1976 International Directory of Mining and Mineral Processing Operations. The figures given here represent annual productive capacity defined in terms of production or output (copper content).

c. Upon completion of Anaconda's smelter modification program, this is expected to rise to 216,000 short tons per year (18,000 short tons per month).

   These figures are exclusive of Anaconda's new Arbiter plant near Anaconda, Montana. At this plant, production commenced in October, 1974; it was temporarily shut down in July, 1975 and was reopened in August, 1976. The Arbiter plant is expected to have a capacity of approximately 36,000 short tons of cathode copper production per year.

   See The Anaconda Company, Proxy Statement for a Special Meeting of Shareholders to be Held October 20, 1976, p. 71.

d. Exclusive of modifications underway expected to expand the existing capacity.

e. The figures given here for Phelps Dodge Corporation are exclusive of the company's new Hidalgo smelter, at Playas in Hidalgo County, New Mexico, which is the first copper smelter in the United States to use flash smelting process developed in Finland. The Hidalgo smelter, which started operations on July 1, 1976 and produced 37,944 short tons of copper anodes in 1976, is expected to have a productive capacity of 100,000 short tons per year.

TABLE II-4

UNITED STATES COPPER REFINERY CAPACITY AT YEAR-END 1974, 1975 AND 1976[a]

(annual capacity, short tons of refined copper production)

Company, Location	Type[b]	At end of 1974	At end of 1975	At end of 1976
PRIMARY PRODUCERS				
Anaconda		295,000	252,000	252,000
Great Falls, Montana	E	180,000	252,000	252,000
Raritan Copper Works, Perth Amboy, N.J.[c]	E	115,000	-	-
Asarco		642,000	744,000	576,000
Baltimore, Maryland[d]	E	318,000	-	-
Perth Amboy, N.J.[e]	E	168,000	168,000	-
Tacoma, Washington	E	156,000	156,000	156,000
Amarillo, Texas	E	-	420,000	420,000
Kennecott		565,000	565,000	565,000
Garfield, near Magna, Utah	E	186,000	186,000	186,000
Anne Arundel County, Maryland	E	276,000	276,000	276,000
Hurley, New Mexico	LF	103,000	103,000	103,000
Phelps Dodge		537,000	537,000	537,000
El Paso, Texas	E	420,000	420,000	420,000
El Paso, Texas	LF	25,000	25,000	25,000
Laurel Hill, L.I., N.Y.	E	72,000	72,000	72,000
Laurel Hill, L.I., N.Y.	LF	20,000	20,000	20,000
Magma (subsidiary of Newmont)		200,000	200,000	200,000
San Manuel, Arizona	E	200,000	200,000	200,000
White Pine (subsidiary of Copper Range)		90,000	90,000	90,000
White Pine, Michigan	LF	90,000	90,000	90,000
Inspiration		70,000	70,000	70,000
Inspiration, Arizona	E	70,000	70,000	70,000
SUBTOTAL		2,399,000	2,458,000	2,290,000
SECONDARY REFINERS				
United States Metals Refining Co. (a subsidiary of AMAX, Inc.) Carteret, N.J.	E, LF[f]	260,000	260,000	260,000
Cerro Copper and Brass, Div. of Cerro Corp., St. Louis, Mo.	E	44,000	44,000	44,000
Chemetco, Inc., Alton, Illinois	E	40,000	40,000	40,000
Reading Industries, Inc., Reading, Penn.	E	40,000[g]	40,000[g]	40,000[g]
Southwire Co., Carrollton, Ga.	E	65,000[h]	65,000[h]	65,000[h]
SUBTOTAL		449,000	449,000	449,000
TOTAL		2,848,000	2,907,000	2,739,000

NOTES AND SOURCES: ACCOMPANYING TABLE II-4

a. Except otherwise noted, data for 1974 and 1975 are based on American Bureau of Metal Statistics, Inc., (ABMS), Nonferrous Metal Data for 1974 and 1975; data for 1976 are estimates based on miscellaneous sources, including individual company annual reports and 10-K forms filed with the Securities and Exchange Commission.
b. E: Electrolytic; LF: Lake and fire refined.
c. Permanently closed in May, 1975.
d. Permanently closed in December, 1975.
e. Permanently closed in March, 1976.
f. Electrolytic: 175,000 short tons/yr.; Lake and fire refining: 85,000 short tons/yr.
g. These figures differ substantially from those listed in ABMS (see Note "a" above); based on data given in Reading Industries, Inc., Form 10-K, for the fiscal year ended December 31, 1975, p. 6.
h. These figures differ somewhat from those listed in ABMS (see Note "a" above); based on data given in Southwire Co., 1975 Annual Report, p. 12.

TABLE II-5

CONSUMPTION OF COPPER IN THE UNITED STATES, 1950-1974
(copper content, in thousands of short tons)

Year	Total	Refined Copper[b]	Scrap	Percent Composition (%) Total	Percent Composition (%) Refined Copper[b]	Percent Composition (%) Scrap[c]
1950	2272.2	1482.2	790.0	100.0	65.2	34.8
1955	2418.7	1536.7	882.0	100.0	63.5	36.5
1960	2079.3	1372.3	707.0	100.0	66.0	34.0
1965	2995.4	2034.4	961.0	100.0	67.9	32.1
1970	2930.5	2044.0	886.5	100.0	69.7	30.3
1971	2956.0	2017.8	938.2	100.0	68.3	31.7
1972	3266.2	2236.2	1030.0	100.0	68.5	31.5
1973	3481.7	2445.6	1036.1	100.0	70.2	29.8
1974[a]	3106.2	2156.6	949.6	100.0	69.4	30.6
(Average annual compound growth rate)						
1950-1970	1.28	1.62	0.58	-	-	-
1950-1974	1.31	1.57	0.77	-	-	-
1960-1973	4.04	4.54	2.98	-	-	-
1960-1974	2.91	3.28	2.13	-	-	-

Notes:
a. Preliminary.
b. Includes copper refined from scrap.
c. Refers to directly consumed scrap.

Source: Copper Development Association, Copper Supply and Consumption 1950-1969; 1955-1974.

and increasing share of total U.S. consumption during this period, with directly consumed scrap reaching barely over 30 percent by 1974. It should be noted, however, that during this same period the share of refined copper from scrap at smelters and refiners in total refined copper production has increased from 14.3% in 1950 to 22.6% in 1974. Consequently, refined copper production from scrap plus directly consumed scrap, taken together, account for a larger share of total consumption (i.e., 46.1% in 1974).

Demand for copper is a derived demand, since it is used as an intermediate input in the production of final goods which are ultimately demanded for consumption or investment. Semifabricators, which alter the shape of copper inputs into products for final use, are the "first-line" consumers of copper.

Among semifabricating industries in 1974, wire mills, which use only refined copper, accounted for 47% of total copper consumption. Brass mills, which consume refined copper and scrap in fairly equal proportions, accounted for about 39% of total consumption. Ingot makers, who use almost entirely scrap, were the third largest consumers at seven percent. Foundries, consuming predominantly scrap, used about four percent, with powder plants, and "other industries" accounting for the remainder.

The major end-use industries consuming semifabricated goods are electrical and electronics products, building construction, consumer and general products, industrial machinery and equipment, transportation, and ordnance and accessories.

The largest use of copper is in electrical equipment and supplies. The manufacture of electric motors, power generators, motor-generator sets, dynamotors, fans, blowers, industrial controls, and related apparatus requires copper for the best electrical performance. Electrical instruments and test equipment, power distribution systems including transformers, bus bars, and switchgear, and electric lighting and wiring equipment require large quantities of copper. Electronic navigation and communication systems also rely on copper in the form of cable and related electric parts. Although aluminum is used for virtually all high-voltage overhead power transmission lines, copper is widely used in underground lines and dominates the smaller gage wire market.

Although industry observers are not in complete accord on the prevalence and importance of long-run substitution in demand (LRS), and comprehensive and detailed quantitative information is unavailable on the degree to which LRS has actually occurred in the industry during the past thirty years, it is generally agreed that aluminum has been the most serious competitor to copper. The greatest replacement of copper has been in the power wire and cable sector, where some 40 percent of insulated power cable and over 90 percent of bare conductor applications are now provided by aluminum.

Copper and aluminum are also mutually interchangeable in some heat exchanger applications. The largest use of copper in the area, automobile radiators, is vulnerable to aluminum. Heat exchangers in household freezers and refrigeration and automotive air-conditioners are predominantly aluminum, while desalination and marine exchangers remain predominantly copper or copper-base alloys.

Available econometric studies of demand for copper generally indicate substantial inelasticity (or insensitivity) in the short-run with respect to movements in (own) prices and macroeconomic activity levels. The long-run elasticity estimates are all greater than the short-run estimates, indicating that the response of demand to relative prices and activity is, indeed, more sensitive in the long-run.

3. Prices

Historically, copper has been marketed at prices based on a number of different systems, some of them quite complex. Nevertheless, two basic pricing channels can be distinguished, the producer prices and prices related to quotations on a metal/commodity exchange. Table II-6 presents trends in copper prices during the postwar period.

Producer prices are prices set independently by the major primary producers at which primary refined copper is sold. In the United States, the domestic producers' price is a set of nearly uniform price quotations used by the major U.S. primary producers and, for a good part of the postwar period and by Noranda, one of the Canadian producers, for sales in the United States. During the postwar period, about 75 percent of all refined copper production in the United States has been sold at the domestic producers' prices.

Prices related to quotations on a metal/commodity exchange refer to prices at which copper is sold internationally (outside North America) by most producers most of the time, related through various formulas to prices prevailing principally on the London Metal Exchange (LME). The LME and the New York Commodity Exchange (COMEX) are the two organized metal exchanges (markets). Of the two, the LME is generally considered to be the more important in terms of turnover, physical deliveries, and its influence on the pricing of copper in general: most of the "formulas" for pricing copper that are found on long-term contracts are related, in one way or another, to LME prices, since LME prices are generally considered to reflect, without delay, changes in the supply and demand situation worldwide. It is important to emphasize that the LME and COMEX are basically hedge and speculative, rather than physical markets.

In addition (and related) to these two basic copper pricing channels, a number of others can be distinguished, under the collective title of price prevailing in the "outside market". With reference to copper markets in the United States, the "outside market" encompasses all trade in copper apart from sales made by the primary producers. The outside market encompasses the secondary industry (including scrap dealers and secondary

TABLE II-6

PRICES OF REFINED COPPER, COPPER SCRAP AND REFINED ALUMINUM IN THE UNITED STATES, 1947-1976
(Yearly averages, cents per pound)

Year	U.S. Producer Refined Copper[a]	LME Refined Copper[b]	Scrap Copper[c]	U.S. Producer Refined Aluminum[d]
1947	21.0	23.5	16.2	15.0
1948	22.0	24.1	17.3	15.7
1949	19.2	21.9	13.9	17.0
1950	21.2	22.3	17.7	17.7
1951	24.2	27.5	21.3	19.0
1952	24.2	32.3	19.0	19.4
1953	28.8	32.2	22.4	20.9
1954	29.7	31.3	24.5	21.8
1955	37.5	43.9	33.6	23.7
1956	41.8	41.0	31.6	24.0
1957	29.6	27.4	20.1	25.4
1958	25.8	24.8	17.6	24.8
1959	31.2	29.8	22.6	24.7
1960	32.1	30.8	21.2	26.0
1961	29.9	28.7	21.8	25.5
1962	30.6	29.3	21.6	23.9
1963	30.6	29.3	22.2	22.6
1964	32.0	44.0	26.0	23.7
1965	35.0	58.6	34.5	24.5
1966	36.2	69.1	44.7	24.5
1967	38.2	51.2	33.2	25.0
1968	41.8	56.0	32.8	25.6
1969	47.5	66.3	42.9	27.2
1970	57.7	62.9	39.5	28.7
1971	51.4	49.3	27.6	29.0
1972	50.6	48.5	39.0	26.4
1973	58.9	80.8	50.2	25.0
1974	76.6	93.1	54.9	34.1
1975	63.5	56.1	33.9	39.8
1976	68.8	63.9	51.6	44.3

Notes and Sources:

a. U. S. producer refinery wirebar f.o.b. (i.e., U. S. producer delivered price minus shipping cost; the shipping cost was 0.9¢/lb. effective August 1, 1976): Metals Week, Engineering and Mining Journal.

b. Official morning session prices on the London Metal Exchange; electrolytic wirebars, monthly average, settlement price: Metal Bulletin, American Bureau of Metal Statistics Yearbook and Engineering and Mining Journal.

c. Estimated New York area delivered price from clean No. 2 heavy copper scrap (No. 1 prior to 1956): Metal Statistics and Engineering and Mining Journal.

d. Major U. S. producer (list) ingot price: Metals Week, Engineering and Mining Journal.

refiners), some of the smaller domestic producers of refined copper selling at premiums over the price of the major domestic producers, and the merchants. More broadly, the "outside market" also includes, with reference to the United States, transactions in physical copper on the LME and COMEX plus imports based on LME quotations.

As indicated, demand for copper is quite inelastic in the short-run, and the supply of copper is basically slow, characterized by long adjustment periods. Hence, wide swings in demand over the business cycle in industrial countries, combined with speculative activity in the very short-run on the two organized commodity exchanges, have contributed to the volatility of copper prices internationally. However, U. S. domestic producers' prices, while lagging LME prices, have generally been considerably more stable. Generally speaking, the domestic primary producers appear to possess discretionary pricing power. In response to persistent demand shifts, they have tended to change their prices only slowly and not by the magnitude often experienced by the LME price, such that the producers' prices have generally remained well below LME prices during periods of strong demand and above LME prices during periods of weak demand. Thus, during periods of rising or excess demand for refined copper, participating producers (U. S. and some foreign) chose to ration their available copper supplies to customers at a price below the level of the LME price rather than increase their price.

There appears to be no complete, simple, logical explanation or set of explanations for the divergence, over certain periods, between the U. S. producers' and the LME prices.

All of the proposed explanations are either logically inconsistent and/or are unable to explain certain "anomalous" behavior on the part of the producers.

Neither copper price fluctuations nor the presence of a two-price system for copper should mask the important point that the long-run price of copper tends to equal the price that is sufficient to induce continued investment. This price, which may be regarded as the long-run economic cost of producing copper, is thought to have increased sharply in recent years after having remained fairly steady over a long period. Hence, despite the fact that a number of factors appear to have had substantial restraining influence on the pricing decisions of the domestic primary producers (e.g., the threat of long-run substitution from aluminum, potential competition from abroad, the presence of U.S. government stockpiles, etc.), costs of production in the face of deteriorating ore grades effectively provide a rising floor for copper prices in the long-run.

4. Financial Performance

In recent years, the U.S. copper industry has experienced modest growth in sales, low return on invested capital, eroding profit margins and higher debt, reflecting the combined pressure of inflation, higher cost of capital, increased capital requirements for environmental control and the worst recession during the postwar period.

Overall profitability for the copper producers, in terms of operating margin on sales, declined from about 23% in 1967 to 19% in 1974. Over the same period, profit margins for large industrial companies and manufacturers in general was rather stable. In terms of after-tax return on stockholders' equity, copper producers have shown a rate of return equal to the Federal Trade Commission (FTC) average for all manufacturing. However, the copper industry has been characterized by much greater volatility in its rate of return. This, in turn, stems from the cyclicality of the industry and fluctuations in copper prices.

Capital expenditures by most companies increased sharply in recent years. A significant portion (i.e., about 25%) of the total industry capital expenditures over the period 1972-1975 has been for pollution abatement, mostly associated with SO_2 controls at smelters. About 60% of the total, however, represents investment in mining and milling capacity.

With capital expenditures increasing faster than internal cash generation (from earnings, depreciaton, and deferred taxes), the cash-flow position of the companies deteriorated. Consequently, there has occurred in recent years a sharp increase in external financing. Over the last five years, overall debt has approximately doubled, while equity has increased significantly. Indeed, some companies are believed to have temporarily reached prudent limits to debt in their capital structure and await higher earnings and stock prices to restore balance and financing flexibility.

Selected comparative financial statistics for principal U. S. copper and other nonferrous metals producers, recent trends in profitability and long-term debt are presented in Tables II-7-10.

TABLE II-7

SUMMARY OF SALIENT FINANCIAL ASPECTS OF U. S. COMPANIES

Company	Value of 1974 Production of Primary Copper @ 75¢/lb. (millions of dollars)	1971-1974 Average Operating Margin on Total Company Sales (percent)	Total Average Capital Spending 1972-1974 (million of dollars)	Level of Operating Profit @ 75¢/lb. Copper, Co. Average Margin Only on Primary (millions of dollars)	Employment Levels[c] Mining, Milling, Smelting and Refining	Long Term Debt as Percent of Total Capitalization	Common Stock at 12/31/75 Book Value $/Share	Market Value % Book
Amax	$149	15.1%	$ 227	22.5	1,500	27%	42.7	111
Anaconda	285	10.2	145	29.1	5,500	28[d]	54.8	31
Asarco	159[f]	6.7	101	10.7[f]	3,400	28	32.2	41
Cities Service	61	17.5[a]	370	10.7	2,000	32	60.5	64
Copper Range	101	13.4	6	13.5	2,800	23	44.9	41
Cyprus Mines	150	31.7	43	47.6	2,000	23[e]	29.4	74
Inspiration Consolidated	113[b]	24.4	29	27.6	2,200	26	35.1	59
Kennecott	603	19.0	187	114.6	11,000	21[d]	42.2	73
Newmont	225	29.9	48	67.3	4,400	27[e]	26.4	87
Pennzoil (Duval)	197	15.9	267	31.3	2,600	55[e]	15.5	125
Phelps Dodge	421	20.4	182	85.9	7,500	37	43.4	84

Notes:
- a. Figure used in Standard & Poor's Copper Composite Average.
- b. Figure used is 1973 deliveries basis; 1974 figure not representative due to production difficulties.
- c. The employment level in U. S. primary copper production totals 45,000 for the above companies.
- d. Total capitalization includes minority lease obligations.
- e. Total capitalization includes minority interests.
- f. Based on total Asarco mine production, of which the domestic U. S. share accounts for 78%. Average earnings from primary metals sales were $4 million pretax. If prorated based on sales, copper would have accounted for $12.8 million.

Source: Arthur D. Little, Inc. estimates.

The information presented above has been obtained from company annual reports and SEC filings, statistical services, financial manuals, and other sources believed to be reliable, but its accuracy and completeness are not guaranteed.

While reasonable care has been taken in data compilation and presentation, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of earnings, and differences in accounting. However, to the best of our knowledge, the above data present an accurate and meaningful basis for selective comparisons.

TABLE II-8

TRENDS IN OPERATING PROFIT MARGIN
(Percent of sales)

Year	Large Industrial Companies[a]	Major Copper Companies[b]
1964	15.9	22.7
1965	16.2	26.5
1966	16.4	29.3
1967	15.5	23.9
1968	15.8	22.9
1969	15.4	27.8
1970	14.5	23.4
1971	14.6	15.5
1972	15.0	16.6
1973	15.8	19.1
1974	15.4	18.7

Notes and Sources:
a. Standard & Poor's composite data, 425 industrials.
b. Standard & Poor's composite data, based on Anaconda, Copper Range, Inspiration Consolidated, Kennecott Copper, Newmont Mining, and Phelps Dodge.

TABLE II-9

INDICATORS OF THE NEED FOR CAPITAL FUNDS

Company	5-Year Growth in Plant Equipment %	5-Year Cash Flow as % of Total Growth Needs
Amax	102%	53%
Asarco	97	78
Anaconda	43	61
Cities Service	30	72
Copper Range	38	94
Cyprus Mines	a	96
Inspiration Consolidated	192	64
Kennecott	47	83
Newmont Mining	b	76
Phelps Dodge	92	62
Pennzoil Company	15	57[c]

Notes:
a. Not available for purposes of comparison. The 442% reflects IMS/Cyprus method of reporting, accounting, and restating for consolidation of subsidiaries over the period in question.
b. Not meaningful for purposes of comparison, due to large investment holdings.
c. Capital expenditures net of retirement and disposals in some years.

Source: Arthur D. Little, Inc. All other figures are as presented by Business Week's Capital Survey, September 22, 1975.

TABLE II-10

RATES OF RETURN ON STOCKHOLDERS' EQUITY
(Percent)

Years	FTC All Manufacturing Pre-Tax	FTC All Manufacturing After Tax	Average of Major Copper Companies Pre-Tax	Average of Major Copper Companies After Tax	Inflation Rate[b]
1965	21.9	13.0	19.7	13.0	1.8
1966	22.5	13.5	20.9	14.0	2.7
1967	19.3	11.7	13.0	9.1	3.5
1968	20.8	12.1	17.2	11.7	3.3
1969	20.1	11.5	22.5	15.3	4.9
1970	15.7	9.3	20.3	14.8	5.5
1971	16.5	9.7	5.5	4.2	4.4
1972	18.4	10.6	12.0	9.5	3.6
1973	21.8	13.1[a]	18.2	13.5	5.5
1974	23.4	14.9[a]	18.9	13.8	10.4
Averages	20.0	11.9	16.8	11.9	NA
Standard Deviation (%)	2.6(13)	1.8(15)	5.2(31)	3.4(29)	NA

Notes: a. Fortune 500 all-industry median was 12.4% in 1973 and 13.6% in 1974.
b. GNP Implicit Deflator, (1958 = 100).
NA: Not Available.

Sources: Federal Trade Commission, Division of Financial Statistics, Quarterly Financial Report for Manufacturing, Mining, and Trade Corporation, 1975 eds.; and Arthur D. Little, Inc.

C. GENERAL DESCRIPTION OF ASARCO, INCORPORATED

1. Overview

Asarco's business has, for many years, been in the mining, smelting, and refining of nonferrous ores and concentrates, producing therefrom principally copper, lead, zinc, silver, and gold, and recovering related by-products from such operations. The business also includes buying and processing nonferrous scrap and selling the alloys produced, producing and selling coal and asbestos, and producing chemical materials and manufacturing machinery for the metalplating and finishing industry. Asarco's operations are carried on principally in the United States with additional operations in Canada, Mexico, and Peru. Asarco has substantial investments in other mining companies, principally in Australia (Mount Isa Mines holdings--49%), Peru (Southern Peru Copper Corporation--51.5%), Mexico (Industrial Minera Mexico--34%), and has held a substantial interest in Revere Copper and Brass Incorporated (33.4% stock plus convertible debentures).

Asarco accounts for between 10 and 20% of domestic sales of refined copper, lead, and zinc, and somewhat more than one-third of the sales of refined silver. Through its ownership of Lake Asbestos of Quebec, Ltd. in Canada, Asarco has about 6% of the domestic market for asbestos. Coal is its other principal non-metallic product, and Asarco accounts for about 1% of the domestic market, through its Midland Coal Company Division, acquired in late 1970.

Table II-11 succinctly illustrates Asarco's participation in nonferrous metals production in years 1974-1976. Equity in non-consolidated associated companies operating outside the United States accounts for nearly one-fourth of Asarco's assets, and 40% of stockholder's equity.

Sales in 1974 totalled $1,344.1 million, an all-time high. Earnings before taxes and extraordinary items were a record $160.1 million, including $103.4 million ($43.4 million in dividends[1]) in equity earnings of non-consolidated associated companies. In 1975, sales and earnings dropped to $1,004.6 million and $15.4 million pre-tax, respectively. A five-year financial summary (1972-1976) may be found in Table II-12.

Table II-13 presents a consolidated Sources and Uses of Funds statement, for years 1972-1976. Note that Asarco generated $433 million in cash flow over this five-year period, but added $544.6 million to property, and paid $149.0 million in dividends. Its long-term debt

[1] Asarco, Incorporated, 1976 Annual Report, p. 19.

TABLE II-11

ASARCO'S METALS PRODUCTION IN 1974, 1975, AND 1976
(in short tons except otherwise noted)

Metal			1976	1975	1974
Copper (Tons)	Mines	Mission	35,200	26,900	40,300
		Sacaton	22,000	21,900	9,500
		Silver Bell	22,300	18,300	23,500
		San Xavier	11,400	9,700	5,900
		Granduc[a]	8,500	9,300	15,900
		Quiruvilca	3,800	6,200	7,400
		Others	3,500	3,600	4,000
		Total	106,700	95,900	106,500
	Refineries	Amarillo	252,500	30,600	-
		Tacoma	87,300	119,700	117,400
		Perth Amboy	13,800	117,100	127,600
		Baltimore	-	41,800	111,000
		Total	353,600	309,200	356,000
	Associated Companies	Mount Isa[c]	164,100	175,800	167,000
		Southern Peru[b]	156,400	119,600	134,400
		Industrial Minera Mexico[d]	40,200	35,100	37,900
Lead (Tons)	Mines	Buchans	10,900	11,900	13,900
		Leadville	7,300	7,500	6,400
		Park City[g]	3,500	2,300	-
		Others	6,700	3,700	4,400
		Total	28,400	25,400	24,700
	Refineries	Omaha	121,000	118,200	125,800
		Glover	76,300	81,900	72,900
		Total	197,300	200,100	198,700
	Associated Companies	Mount Isa[c]	148,900	146,700	139,200
		Industrial Minera Mexico[e]	96,800	85,600	108,200
		Neptune[f]	1,100	1,400	3,500
Zinc (Tons)	Mines	Tennessee	42,700	47,900	56,400
		Buchans	17,800	19,500	23,400
		Leadville	14,600	14,100	12,800
		Ground Hog	12,700	10,900	12,400
		Quiruvilca	6,200	4,400	4,700
		Park City[g]	4,700	2,700	-
		Quioma	3,100	-	-
		Total	101,800	99,500	109,700
	Zinc Fuming Plants[h]		37,600	41,800	39,600
	Zinc Oxide[i]	Columbus	19,600	14,000	20,700
		Hillsboro	8,800	7,200	15,400
		Total	28,400	21,200	36,100
	Refineries	Corpus Christi	90,200	81,900	81,100
		Amarillo	-	20,400	46,700
		Total	90,200	102,300	127,800
	Associated Companies	Industrial Minera Mexico[k]	146,700	127,300	135,700
		Mount Isa[c]	123,800	126,600	113,400
		Neptune[f]	15,300	11,700	15,700
Silver (Troy Ounces)	Mines	Galena	3,421,000	3,350,000	3,486,000
		Quiruvilca	1,068,000	1,134,000	1,388,000
		Coeur	661,000	-	-
		Buchans	554,000	611,000	741,000
		Mission	407,000	292,000	511,000
		Leadville	335,000	352,000	330,000
		Park City[g]	219,000	161,000	-
		Others	700,000	550,000	644,000
		Total	7,365,000	6,450,000	7,100,000
	Refineries	Amarillo	32,997,000	-	-
		Perth Amboy	11,314,000	44,576,000	37,835,000
		Baltimore	-	10,679,000	16,947,000
		Total	44,311,000	55,255,000	54,782,000
	Associated Companies	Industrial Minera Mexico[e]	18,133,000	17,303,000	20,770,000
		Mount Isa[c]	11,277,000	11,045,000	9,690,000
		Neptune[f]	62,000	98,000	72,000

Notes: General Note: All figures for associated companies represent entire production, not Asarco's share.
a. Asarco's 50% share of copper in concentrates.
b. Blister output plus copper exported in concentrates.
c. Metal content of products for fiscal year ended June 30.
d. Blister output.
e. Refined output.
f. Metal content of products.
g. Asarco's 40% share of metal in concentrates.
h. Metal content of zinc fume recovered from lead smelter slag at El Paso and East Helena.
i. Metal content of zinc oxide.
k. Refined output plus metal content of concentrates and fume sold.

Source: Asarco, Incorporated, 1976 Annual Report, p. 18.

TABLE II-12

SUMMARY OF ASARCO'S BUSINESS PERFORMANCE, 1972-1976

GENERAL NOTE: The following tables set forth, for the five years ended December 31, 1976, the approximate amounts of Asarco's (i) consolidated sales and earnings, before taxes on income, attributable to its principal lines of business and (ii) consolidated sales of principal products and services. Sales figures do not include sales by nonconsolidated associated companies.

Line of Business	1976		1975		1974		1973		1972	
(dollars in thousands)	Sales	Earnings (Loss)	Sales	Earnings (Loss)	Sales	Earnings (Loss)[g]	Sales	Earnings (Loss)[g]	Sales	Earnings (Loss)[g]
Primary metals[a]	$ 815,232	$ 32,920	$ 793,045	$ 27,493	$1,067,658	$ 78,927	$ 875,563	$ 60,911	$ 653,706	$ 27,754
Secondary metals	143,365	2,716	121,698	3,340	192,395	10,706	137,162	1,467	107,754	1,032
Asbestos	81,165	17,298	31,956	(301)	42,867	11,344	25,718	5,376	21,151	3,837
Coal	45,119	2,527	39,190	(3,879)	25,114	(9,923)	18,756	(10,719)	21,514	(5,267)
Other products[b]	18,856	(1,853)	18,749	(309)	16,016	(597)	11,240	86	10,220	1,273
Equity in earnings of nonconsolidated associated companies[c]	-	30,668	-	27,829	-	103,378	-	69,774	-	27,285
Nonoperating[a]	-	(30,098)	-	(18,309)	-	(3,921)	-	(7,108)	-	(3,277)
Unusual items[d]	-	-	-	(20,500)	-	(29,838)	-	2,237	-	-
	$1,103,737	$ 54,178	$1,004,638	$ 15,364	$1,344,050	$106,076	$1,068,439	$122,024	$ 814,345	$ 52,637

Sales	1976		1975		1974		1973		1972	
(dollars in thousands)										
Copper	$ 263,669	24%	$ 167,676	17%	$ 290,316	22%	$ 324,671	30%	$ 263,942	32%
Silver	209,610	19	252,634	25	285,176	21	174,083	16	110,534	14
Lead	89,496	8	81,712	8	143,125	11	110,547	10	67,438	8
Zinc	73,875	7	85,893	9	120,866	9	75,697	7	56,232	7
Secondary metals	143,365	13	121,698	12	192,395	14	137,162	13	107,754	13
Asbestos	81,165	7	31,956	3	42,867	3	25,718	3	21,151	3
Coal	45,119	4	39,190	4	25,114	2	18,756	2	21,514	3
Other products[f]	197,438	18	223,879	22	244,191	18	201,805	19	165,780	20
Total	$1,103,737	100%	$1,004,638	100%	$1,344,050	100%	$1,068,439	100%	$ 814,345	100%

Notes:

a. Includes mining, smelting and refining of copper, silver, lead, zinc and byproducts as well as toll treatment charges for smelting and refining.
b. Primarily ilmenite, limestone, sand and gravel.
c. See note 4 of note to financial statement (i.e., Footnote "g" below).
d. Primarily dividends and interest on investment (other than those accounted for by the equity method), patent royalties and interest expense.
e. See note 11 of notes to financial statement (p. 29 of "Source" noted below).
f. Includes byproducts, ilmenite, toll treatment charges, etc.
g. Restated as follows: (Note 4: Investments, Asarco Incorporated, 1976 Annual Report, p. 26): Dividends from companies accounted for by the equity method were (in millions): 1976—$10.0; 1975--$22.0; 1974--$43.3; 1973--$15.3; 1972--$18.9.

Taxes have not been provided on the undistributed earnings of associated companies more than 50% owned and corporate joint ventures, accounted for by the equity method, as such earnings have been reinvested indefinitely, and no remittance of such earnings to Asarco is foreseen. At December 31, 1976, the cumulative amount of equity in such undistributed earnings on which income taxes have not been recognized is $218.1 million.

Source: Asarco, Incorporated, 1976 Annual Report, p. 31.

TABLE II-13

ASARCO, INCORPORATED AND CONSOLIDATED SUBSIDIARIES
CONSOLIDATED STATEMENT OF CHANGES IN FINANCIAL POSITION
(for the years ended December 31)

	1976	1975	1974[a]	1973[a]	1972[a]
	(dollars in thousands, except per share amounts)				
Cash and Marketable Securities, beginning of year	$ 34,599	$ 20,239	$ 19,618	$ 15,097	$ 10,379
Source of Funds:					
Net earnings	42,313	25,438	124,620	99,439	43,584
Add expenses not requiring outlay of funds:					
Depreciation and depletion	50,667	36,484	34,877	26,801	23,928
Deferred income taxes	1,326	(2,884)	6,009	(983)	1,138
Estimated costs of plant closings and partial mine write-off	-	20,500	29,838	19,700	-
Equity in earnings of nonconsolidated associated companies, in excess of dividends received	(20,701)	(5,847)	(60,025)	(54,470)	(8,386)
Funds provided from operations	73,605	73,691	135,319	90,487	60,264
Long-term debt incurred	92,000	232,180	38,370	50,750	16,500
Funds committed to construction	(69,525)	19	2,544	11,873	(14,436)
Proceeds from sale of future production	10,000	13,000	-	-	-
Other, net (including materials and supplies)	3,854	(9,237)	(21,025)	6,362	23
	109,934	309,653	155,208	159,472	62,351
Use of Funds:					
Inventories	(59,200)	20,243	33,032	(15,450)	(8,527)
Investments, net	22,892	(325)	(17,806)	(9,472)	(232)
Property	76,039	167,495	137,666	96,679	66,732
Accounts receivable	1,668	(6,691)	(11,112)	37,773	9,456
Current liabilities, other than estimated costs of plant closings provided in the current year	20,283	80,842	(38,382)	3,616	(47,794)
Long-term debt reductions	33,490	6,687	13,580	10,083	3,600
Dividends	18,721	28,148	38,103	32,040	32,097
Treasury stock, net	209	(1,106)	(494)	(318)	2,301
	114,102	295,293	154,587	154,951	57,633
Cash and Marketable Securities, end of year	$ 30,431	$ 34,599	$ 20,239	$ 19,618	$ 15,097

Note: a. Restated by Asarco.

Source: Asarco, Incorporated, 1976 Annual Report, pp. 21-29.

increased commensurately from \$51.0 million (\$38.1 million in 1971)[2] to \$400.4 million.[1]

In 1974, a peak year, Asarco had approximately 15,300 employees. Employment dropped to 13,500 in 1975 as a result of the recession and depressed metals market and further dropped to 13,100 in 1976.

2. Analysis of Asarco's Operations in Copper

Asarco's primary metals business typically produces 70-80% of consolidated Asarco sales. Table II-12 indicates that copper has declined in importance over the five-year period 1972-1976. Copper sales of \$263.9 million represented 40% of primary metal sales in 1972; at \$167.7 million in 1975, they represented only 21% of such sales (\$263.7 million in 1976, accounting for 24% of total sales revenues). Lead and zinc revenues as percent of the total have shown greater stability. Silver has increased in importance, from \$110.5 million in 1972 to \$252.6 million in 1975, when it represented 32% of Asarco primary metal sales, and 25% of total consolidated sales. Toll processing charges and by-product sales have fluctuated around 20% of primary metals business revenue.

The average pre-tax earnings of Asarco's primary metals business has been about \$40 million per year, representing a margin of about 5% on sales averaging \$750 million per year. Asarco's entire domestic complex of mines, smelters, and refineries accounts for only about 50% of Asarco's total pre-tax earnings; this, on an after-tax basis, would be comparable to the cash dividends Asarco receives from its holdings in the foreign ventures Southern Peru Copper (Peru), M.I.M. (Australia), and Industrial Minera (Mexico).

3. Asarco's Domestic Copper Mining, Smelting and Refining Operations

Approximately 31% of the copper content received by Asarco's smelters during 1976 was attributable to Asarco's own mines, Asarco's share of the production by non-consolidated associated companies and the output of mines under joint ventures; 21% was attributed to purchased materials; and the remaining 48 was treated for others (e.g., Duval) on a toll basis.

Copper production and related data on Asarco's domestic copper mining activities are presented in Table II-14. Ore reserves for Asarco's principal domestic copper mining properties are shown in Table II-15.

Asarco owns and operates three copper smelters located at El Paso, Texas; Hayden, Arizona; and Tacoma, Washington. In addition to treating its own mine production, Asarco is a custom smelter and refiner in that it purchases ores and concentrates from other domestic and foreign producers for its own account. It also processes material owned by others on a toll basis.

---

[1] Ibid., p. 23.

[2] Asarco, Inc., 1973 Annual Report, p. 31, "Ten Year Financial Summary, 1964-1973".

TABLE II-14

ASARCO'S DOMESTIC COPPER MINING ACTIVITIES

	Ore Milled (Short Tons)	Mineral Content: Copper (%)	Mineral Content: Silver (Ounce/ Short Ton)	Mineral Content: Molybdenum (%)	Copper Produced (Short Tons)
Mission:					
1972	8,400,000	0.61	.12	.032	45,400
1973	8,800,000	0.60	.16	.017	46,600
1974[a]	7,500,000	0.61	.14	.019	40,300
1975[b]	5,100,000	0.60	.10	.020	26,900
1976[c]	6,407,000	0.62	.12	.019	35,200
Sacaton:					
1974[c]	2,020,000	0.63	0.05	-	9,500
1975	3,630,000	0.74	0.06	-	21,900
1976	3,782,000	0.71	0.07	-	22,000
San Xavier:					
1972	-[d]	0.81	-	-	600
1973	840,000	0.61	-	-	2,700[e]
1974[a]	1,220,000	0.77	-	-	5,900[e]
1975	1,370,000	1.05	-	-	9,700[e]
1976	1,317,000	1.12	-	-	11,400[e]
Silver Bell					
1973	3,800,000	0.60	.08	.013	23,600[e]
1973	3,900,000	0.64	.05	.012	23,800[e]
1974	3,800,000	0.65	.06	.016	23,500[e]
1975[b]	2,500,000	0.72	.07	.016	18,300[e]
1976[b]	3,084,000	0.72	.07	.016	22,300[e]

Notes:
a. Operations at Mission and San Xavier were affected by a five-week strike in 1974.
b. Affected by production curtailments throughout 1975 and through mid-1976 as a result of weak demand for copper.
c. Production commenced in May 1974 reaching designed capacity of 9,000 tons per day late in year.
d. Approximately 100,000 tons per year of copper-bearing oxide ore produced by San Xavier was used as flux material at Asarco's Hayden, Arizona, and El Paso, Texas, copper smelters.
e. Includes copper attributable to precipitates produced by leaching operations at these mines. At San Xavier, all of the oxide ore is treated by leaching.

Source: Asarco, Inc., 1976 Form 10-K filed with the Securities and Exchange Commission, p. A3.

TABLE II-15

ASARCO'S DOMESTIC COPPER ORE RESERVES
(December 31, 1976)

	Ore Reserves[a] (Short Tons)	Average Copper Content (%)
Mission	141,200,000	0.73
Sacaton		
open pit	24,200,000	0.70
underground	16,700,000	1.23
San Xavier		
oxide ore	3,300,000	1.04
sulfide ore	167,400,000	0.52
Silver Bell	24,800,000	0.66

Note: a. Given in terms of copper content.

Source: Asarco, Inc., 1976 Form 10-K filed with the Securities and Exchange Commission, p. A4.

Table II-16 shows the material processed and the blister copper produced at each of Asarco's copper smelters for the five-year period 1972-1976.

During 1976, the El Paso, Hayden and Tacoma smelters operated at approximately 80%, 65% and 74%,[1] respectively, of effective capacity.

Smelting operations at the El Paso, Hayden and Tacoma smelters are curtailed from time to time, with resulting losses in production, to comply with air quality regulations. All three copper smelters are equipped with ambient air monitoring and meteorological measuring systems.

The Tacoma smelter treats material high in arsenic and antimony content from both foreign and domestic sources and is the sole domestic producer of arsenic trioxide and metallic arsenic. Arsenic trioxide is a raw material used in the production of pesticides, weed control agents, wood-treating preservatives and other products. Metallic arsenic is used in various specialty alloys.

The Hayden smelter treats principally copper concentrates and precipitates produced by mines in the United States. The El Paso and Tacoma smelters also process the output of southwestern mines, but in addition possess a capability, believed unique among domestic copper smelters, to process a variety of crude copper-bearing materials that contain important recoverable metals in addition to copper and precious metals.

The El Paso copper smelter is operated in conjunction with a lead smelter and cadmium fume and zinc fume recovery units at the same plant site. This combination of facilities permits the extraction of a range of metal values from complex copper-bearing materials including drosses, sludges and other residue materials from other nonferrous smelting and refining operations. A plant to produce commercial grade antimony metal with a designed capacity of 1,200 tons of antimony per year is under construction at El Paso. The estimated cost of the new plant is $7.0 million and completion is planned for mid-1977. This plant will treat tetrahedrite--a complex copper-antimony-silver mineral.

---

[1]This implies "effective" smelter capacity at Tacoma of about 112,000 short tons per year of copper production as of 1976. However, similar figures on production and capacity utilization for 1974 given in Asarco, Inc., 1974 Form 10-K (p. A6) imply "effective" capacity of about 119,000 short tons per year of copper production as of 1974.

For analytical purposes, however, we believe the implicit "effective" smelter capacity figures derived from Form 10-K production and capacity utilization data are misleading. We estimate Tacoma's maximum production from sulfur-bearing materials, before unit costs would start rising significantly, to be about 78,000 short tons a year of copper production. To this is added another 22,000 short tons a year or production from precipitates and scrap, which is higher than actual peak production (in 1974) from this source. Tacoma's "effective" smelting capacity (i.e., the point beyond which unit costs would start rising sharply) is hence estimated at about 100,000 short tons of copper production per year.

TABLE II-16

PRODUCTION AT ASARCO'S COPPER SMELTERS, 1972-1976

Years	Material Processed--(Short Tons) El Paso	Hayden	Tacoma	Total
1972	365,000	755,000	406,000	1,526,000
1973	463,000	746,000	384,000	1,593,000
1974[a]	371,000	614,000	350,000	1,335,000
1975	417,000	522,000	333,000	1,272,000
1976	399,000	523,000	355,000	1,277,000

Years	Blister Copper Produced--(Short Tons) El Paso	Hayden	Tacoma	Total
1972	78,000	160,000	100,000	338,000
1973	98,000	147,000	96,000	341,000
1974[a]	77,000	129,000	87,000	293,000
1975	86,000	105,000	72,000	263,000
1976	83,000	102,000	83,000	268,000

Note: a. Copper smelters were shut down by strikes of about five weeks in 1974.

Source: Asarco, Inc., 1976 Form 10-K filed with the Securities and Exchange Commission, p. A5.

Asarco's copper refineries are located in Amarillo, Texas, and Tacoma, Washington. The refineries process substantially all of the output of Asarco's copper smelters. They also refine blister copper and copper crystals from other smelters on a toll basis and recycle copper scrap. Table II-17 shows production data with respect to Asarco's copper refineries for the five-year period 1972-1976.

During 1976, Tacoma and Amarillo refineries operated at approximately 58% and 68%, respectively, of effective capacity.

Of the 354,000 short tons of refined copper produced by Asarco's refineries during 1976, approximately 26% was attributable to materials produced by Asarco's mines and Asarco's share of the materials produced by nonconsolidated associated companies and under joint ventures, 34% to purchased materials, and 40% was treated for others on a toll basis. Refined copper is sold by Asarco in the form of cathodes, wirebars, cakes, billets, ingot bars and continuous-cast copper rod for use in electrical, transportation, construction, electroplating and other applications.

Asarco completed construction in 1976 of the copper refinery at Amarillo, Texas. All elements of the $196 million plant have now been activated with a minimum of start-up problems. Amarillo has a designed capcity of 420,000 short tons of refined copper per year and is being operated currently at a rate of 265,000 short tons of copper per year. The Amarillo refinery replaces the Company's obsolescent East Coast refineries at Baltimore and Perth Amboy. Asarco anticipates that sufficient blister copper will be available from its own smelters and from other sources for effective utilization of the Amarillo refinery.

4. Pollution Control Expenditures[1]

Capital expenditures reported by Asarco in order to comply with pollution control standards in the past five years have been as follows: 1972: $21.7 million; 1973: $23.9 million; 1974: $19.9 million; 1975: $22.0 million; 1976: $31.9 million. Major projects have included sulfuric acid plants at Asarco's Hayden and El Paso copper smelters and a liquid sulfur dioxide plant at the Tacoma copper smelter. Of these capital costs, $24 million were recouped from outside shippers under a surcharge formerly in effect. In addition to capital expenditures, pollution control operating and maintenance costs amounted to approximately $11.7 million, $14.7 million, $16.5 million, $21.0 million, and $31.9 million, respectively, in the years 1972 through 1976. Since January 1, 1976, the operating expenses included in environmental costs are net after sales revenue of sulfur dioxide and sulfuric acid.

[1]For a more complete discussion refer to Asarco, Inc., 1976 Form 10-K filed with the Securities and Exhange Commission, pp. A17-A18.

TABLE II-17

PRODUCTION AT ASARCO'S COPPER REFINERIES, 1972-1976

Years	Refined Copper Produced--(Short Tons)				
	Amarillo	Baltimore	Perth Amboy	Tacoma	Total
1972	-	211,000	154,000	120,000	485,000
1973	-	138,000	155,000	120,000	413,000
1974[a]	-	111,000	128,000	117,000	356,000
1975	30,000[b]	42,000[c]	117,000	120,000	309,000
1976	253,000	-	14,000[d]	87,000	354,000

Notes:
a. Copper refineries were shut down by strikes of about five weeks in 1974.
b. Production commenced September 1975.
c. Terminated copper refining operations June 1975.
d. Terminated copper refining operations March 1976.

Source: Asarco, Inc., 1976 Form 10-K filed with the Securities and Exchange Commission, p. A6.

Asarco estimates that further known future capital expenditures to comply with pollution control standards over the next few years totals about $94 million (as of year-end 1976), and may affect many of Asarco's facilities. Major projects, which were begun in 1975, include a four-year program at the El Paso plant to reduce dust and fugitive emissions and treat waste gases and a three-year program at the East Helena plant to treat waste gases. Estimated future expenditures for the El Paso and East Helena projects totaled $67.6 million and $14.4 million, respectively, as of December 31, 1976. In addition, a $7 million program to reduce further the amounts of arsenic-bearing particulate matter emitted and to provide better control of low-level sulfur dioxide emissions at the Tacoma plant was started in 1976. A two-year project to construct a new acid plant at Corpus Christi has recently been completed at a cost of approximately $15.4 million.

On February 19, 1976, the Puget Sound Air Pollution Control Agency (PSAPCA) granted a variance from certain local air pollution regulations to Asarco's Tacoma, Washington, smelting and refining facility. The terms provide for a variance from specific air regulations pertaining to particulate matter, arsenic and sulfur dioxide for periods ranging from two (2) years to five (5) years. Asarco's variance applications proposed a program, estimated to cost $7 million, directed toward further control of particulate and arsenic emissions, and fugitive emissions of sulfur dioxide.

5. Pollution Control Costs and Financing Limitations

Table II-18 indicates that for the period 1971-1976 inclusive, Asarco spent over $100 million, or an average of $18 million/year on pollution control equipment (excluding O&M costs). In the past two years this represented about 22% of total capital spending.

The associated O&M cost penalty was estimated by Asarco to have increased from $8 million in 1971 to $32 million in 1976, when it represented about 4% of primary metals sales. This seems to us to be a very significant burden (even allowing for some overestimation on Asarco's part) when it is noted that Asarco's 1971-1976 pre-tax, pre-pollution control margin on primary metals averaged 6.8%.

Asarco's total debt has increased sharply over the last five years, and its pollution control debt has taken a sharp jump recently. Asarco's debt/equity ratio has been increasing steadily since 1971, when it was 5.4% and stood recently at 32%. It reported a ratio of earnings to fixed charges of 3.7 on the parent company consolidated basis, and 2.9 to a total enterprise basis, for 1975; these ratios were 0.8 and 1.0, respectively, as of March 31, 1976.

TABLE II-18

ASARCO'S REPORTED POLLUTION CONTROL (P.C.) COSTS
(in millions of current dollars)

	1976	1975	1974	1973	1972	1971
Capital Expenditures						
Total Property	76.0	167.5	137.7	96.7	66.7	37.4
Pollution Control	31.9	22.0	19.9	23.9	21.7	6.7
Percent of Pollution Control	42.0%	13.0%	14.0%	25.0%	33.0%	18.0%
Operating Costs						
Pollution Control O&M Cost Penalty	31.9	21.0	16.5	14.7	11.7	7.6
Pollution Control Cost as Percent of Primary Metals Sales	3.9%	3.0%	1.5%	1.7%	1.8%	1.5%
Total Pollution Control Costs	63.8	43.0	36.4	38.6	33.4	14.3

Source: Based on Asarco, Inc., Financial Statements.

We think it is interesting and important to note that the sum of pollution control costs, over the period 1971-1976, amounts to 64% of Asarco's net increase in long-term debt obligations of $362 million. Of this total, at least $82 million was specifically designated for pollution control financing as of December 31, 1976. If one assumed all pollution control costs were financed by long-term credit obligations, normal debt service alone would be more than $20 million/year.

In this connection, it is pertinent to note the restrictions on additional financing that may obtain, especially when contemplating, say, a $40-90 million total control package option for Tacoma:

Under 1971-1975 "average" conditions, Asarco could receive about $80 million in cash flow from its worldwide operations, from which it would be expected to pay $30 million or more in dividends to stockholders, and debt maturities. The balance is considerably less than Asarco's recent capital expenditure program, which averaged nearly $100 million per year. Thus, it must look to additional earnings, debt, and equity financing, to make total cash outlays of greater than $50 million per year. There are obviously limits on all counts: on earnings, the limit is the extent to which earnings in the near term will be above average; on equity financing, Asarco's stock at $18/share is substantially below its stated book value of about $31, thus involving substantial dilution of equity in sale at current market prices. A recent proposal for equity financing from its Australian affiliate has apparently been shelved.

On additional debt, Asarco is under restrictive covenants associated with its $70 million of 7-7/8% notes due in 1994--held by three major insurance companies. These require that Asarco meet certain fixed charge and working capital coverage ratios, and limit debt to 82% of stockholders' equity less equity in assets of foreign ventures. Indications are that, as of late 1976, Asarco would require additional equity before additional long-term financing would be feasible. Using 1976 year-end equity figures, the indications are that Asarco, with $400 million in long-term debt, was at or very close to its debt limit under the indenture restrictions.

Under the most ambitious options for Tacoma, Asarco would have to allocate only $10-20 million per year (in constant 1978 dollars) for incremental capital expenditures over the next five or six years. It is not clear that this amount could be accomodated now under "average" business conditions, unless other Asarco capital outlays were reduced and/or deferred. Even then, this does not mean that such expenditures would be economically attractive, since it may fail to meet Asarco's risk-return criteria.

6. Asarco's Cost of Capital

Asarco realized long-term return on equity for the period 1965-1976 inclusive of 12-13% in current dollars. For the most recent five year period, 1972-1976, the return was only about 9-1/2%. If the recession year, 1975, is eliminated, Asarco's return for the latter period becomes 11% on average. When one adjusts this return for inflation, the result is an *ex post* real rate of return of only 5%.

Today, high grade bonds are available which yield 7-9% pre-tax, and high grade preferred stocks are available which yield about 7.5% after tax. Since the nonferrous metals business is highly cyclical and erratic, Asarco would be expected to earn more on its equity than on these relatively risk-free investments.

We believe Asarco's management, like that of other metals/mining companies, traditionally used an *ex ante* equity rate of return criterion or hurdle rate of 12-15% for evaluating investments *of average risk* in the business and economic environment of the 1960's with inflation of 3% or less. This implies a hurdle rate of 9-12% in constant dollar terms. With 5% expected inflation, we would expect Asarco management and stockholders to think in terms of a hurdle rate greater than the return allowed for regulated electric utilities (i.e., 12-3/4-16% return on equity[1], in current dollar terms). This suggests to us a *minimum* Asarco hurdle rate of 10% in constant dollars which would apply to investments of normal business risk to Asarco.

---

[1]See, for example, Blyth Eastman Dillon & Company, Incorporated, Investment Research "Electric Utilities Market Service", Volume V, Number 2, April 1977; and Testimony of Mr. Eugene Meyer of Kidder Peabody & Company, Docket 761-8, New Jersey Board of Public Utility Commissioners, 1976.

III. BACKGROUND INFORMATION RELEVANT TO AN IMPACT ANALYSIS OF ASARCO'S TACOMA SMELTER

A. INTRODUCTION

This Chapter presents background information relevant to the analysis of increased pollution control costs at the Tacoma smelter. This information is organized as follows:

Section B describes briefly the production and pollution control technology in use at the Tacoma smelter. This section is aimed at readers who are unfamiliar with the technological aspects of copper smelting.

Section C describes the historical raw material supply situation.

Section D presents a discussion of the nature of custom and toll smelting contracts and how the accounting system at Tacoma reflects these characteristics.

Section E describes the interrelationships between Tacoma and other Asarco plants.

B. PLANT DESCRIPTION OF THE TACOMA SMELTER AND REFINERY

For completeness, this report presents only a brief description of the Tacoma smelter and refinery. Any reader interested in detail should refer to other reports on this plant (e.g., Pacific Environmental Services (1976),[1] or PEDCo (1976)).[2]

1. Process Flowsheet

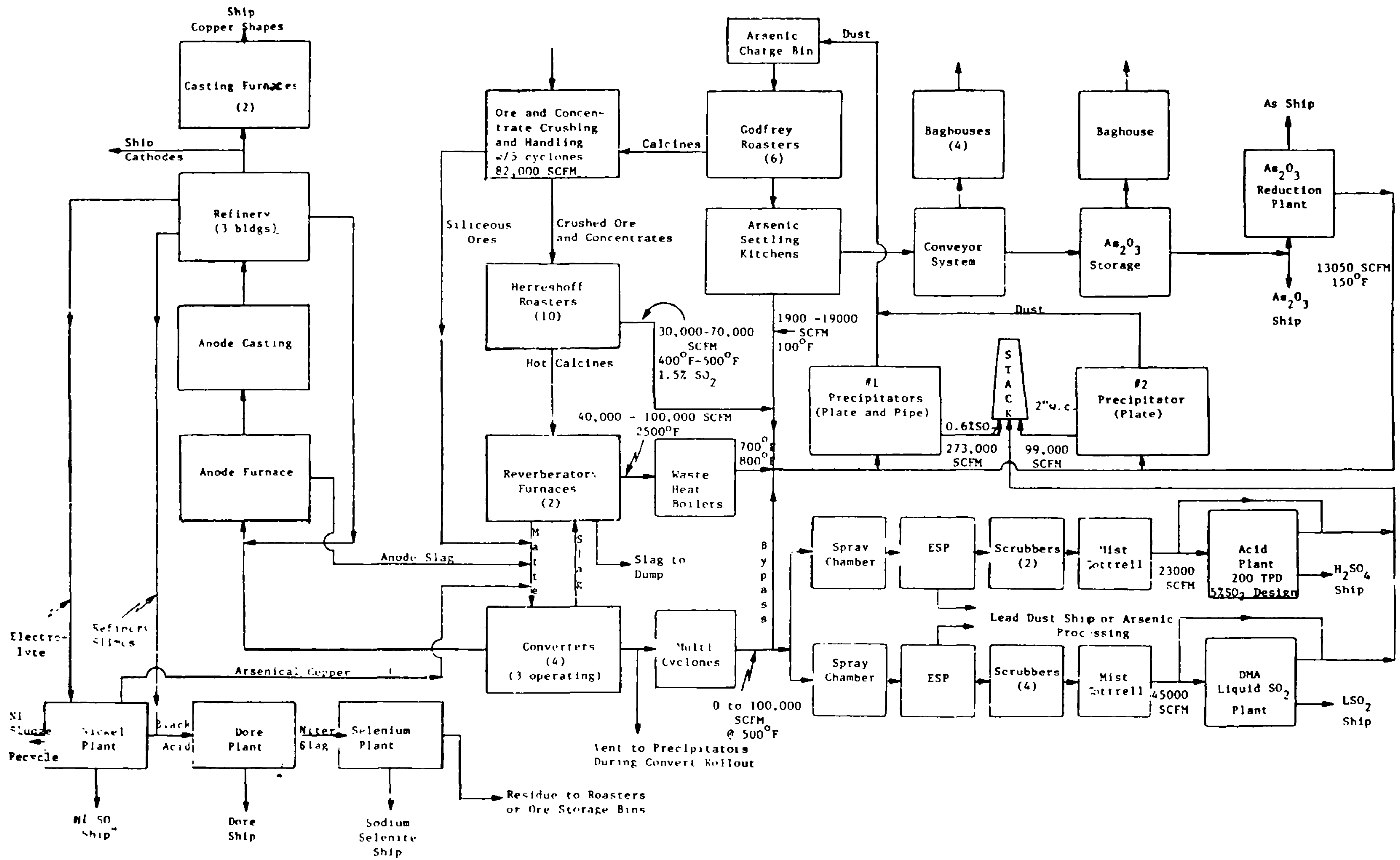
The smelter section of the plant consists of the coarse ore and concentrate handling and crushing equipment, ten multiple-hearth (Herreshoff) roasters, two reverberatory furnaces, four converters, and three anode furnaces. Arsenic processing equipment consists of six Godfrey roasters (four usable), arsenic trioxide settling kitchens, arsenic trioxide storage, and a metallic arsenic plant.

The plant flowsheet is shown in Figure III-1. Concentrates and other feed materials are fed to the multiple-hearth (Herreshoff) roasters. The hot

---

[1] Pacific Environmental Services, (February 1976), "Design and Operating Parameters for Emission Control Studies: Asarco-Tacoma Smelter," EPA 600/2-76-036k.

[2] PEDCo-Environmental, (September 1976), "Evaluation of Sulfur Dioxide and Arsenic Control Techniques for the Asarco-Tacoma Smelter," EPA 68-02-1321, Task Order No. 35.



Source: Pacific Environmental Services, EPA-600/2-76-036K

FIGURE III-1

TACOMA SMELTER PROCESS FLOWSHEET

calcines from the multiple hearth roasters are taken to one of two reverberatory furnaces (only one reverb is normally in use) where they are smelted to a matte containing 35-45% copper. Slag from the furnace is sent to the dump. The matte is tapped into ladles which are carried by crane to the converters.

The converters produce copper which is transferred by ladles to the anode furnace where some minor impurities are removed by fire refining and the molten metal is cast into anodes.

The refinery section consists of two casting furnaces, an electrolytic refinery, a nickel sulfate plant and recovery facilities to reclaim doré (a gold, silver bullion), and a selenium-tellurium containing slag.

The anodes are refined in the electrolytic refinery into cathodes. The cathodes from the refinery are either shipped as such or melted in a cathode furnace, cast, and shipped as standard copper shapes. As a part of the electrolyte purification circuit, nickel sulfate is produced. Refinery slimes are sent to the doré plant which produces doré for shipment and niter slag which is also shipped.

Flue dusts from roasters and reverb containing arsenic are fed to the Godfrey roasters. The arsenic trioxide volatilizes and is passed through arsenic settling kitchens (of which there are three), where the arsenic trioxide is condensed. The arsenic trioxide is in two grades: raw (95% pure) or refined (99% pure). As_2O_3 is shipped or is further processed in a reduction plant and shipped as arsenic metal. The calcine residues from the Godfrey roasters are recycled to the charge preparation area.

2. Existing Pollution Control Equipment

The plant already has some particulate control facilities. As a part of its application for a variance, Asarco has agreed to revamp the particulate control system to increase capture of particulates.

The converter gases are treated in either a liquid SO_2 plant or a sulfuric acid plant for the control of SO_2 emissions. Converter gases pass through a multicyclone before going to individual gas cleaning circuits for the liquid SO_2 and acid plants. The gas cleaning circuit consists of spray chambers, precipitators, scrubbers, and mist precipitators. The tail gases from the liquid SO_2 and acid plants go to the stack. The converter gases can also be bypassed from the precipitator directly to the stack. The particulates recovered from the converter gas stream are shipped to a lead smelter (the East Helena lead smelter of Asarco).

The single contact acid plant handles an average of 23,000 SCFM of gas and produces nominally 153 tons/day of acid. Acid storage capacity is 2,500 tons.

The liquid SO_2 plant processes up to 45,000 SCFM of converter gases. It was built for a design capacity of 200 TPD. The gas stream being weaker than that assumed for design, the operating rate is about 150 TPD. The gaseous SO_2 is absorbed in dimethyaniline (DMA) and then regenerated by steam stripping, as pure SO_2. The SO_2 is liquefied by compression and is then stored under pressure. The DMA concentration plant contains 20,000 gallons of DMA which is passed between the pregnant tank and the strip tank. When there is no SO_2 being generated by the converters, the system operation can be cut back so that very little DMA is processed.

A plan view of the flues between the roasters, reverberatory furnaces, converters, acid plant and liquid SO_2 plant and the stack is shown in Figure III-2. Gases from the multiple-hearth roasters pass into the roaster building flue, then to the roaster chamber or settling flue and then to the junction of the reverberatory furnace flue. Gases from the reverberatory furnaces pass through waste heat boilers, then to the reverberatory furnace flue. The No. 1 brick flue takes most of the gases from the roaster building and the No. 2 brick flue most of the gases from the reverberatory furnaces. A cross-over link is installed to allow system pressure balance. The draft is obtained from the 563 foot high main stack and is 2" WC at the base. The gases from the converter hoods are drawn by two hot gas fans and allowed to pass either to the liquid SO_2 plant, the sulfuric acid plant or the stack. An additional line from the acid plant to the brick flue provides SO_3 from the acid plant to condition the gases for the final precipitator treatment before the stack. The acid plant and SO_2 plant tailgases are vented to the main stack downstream of the precipitators.

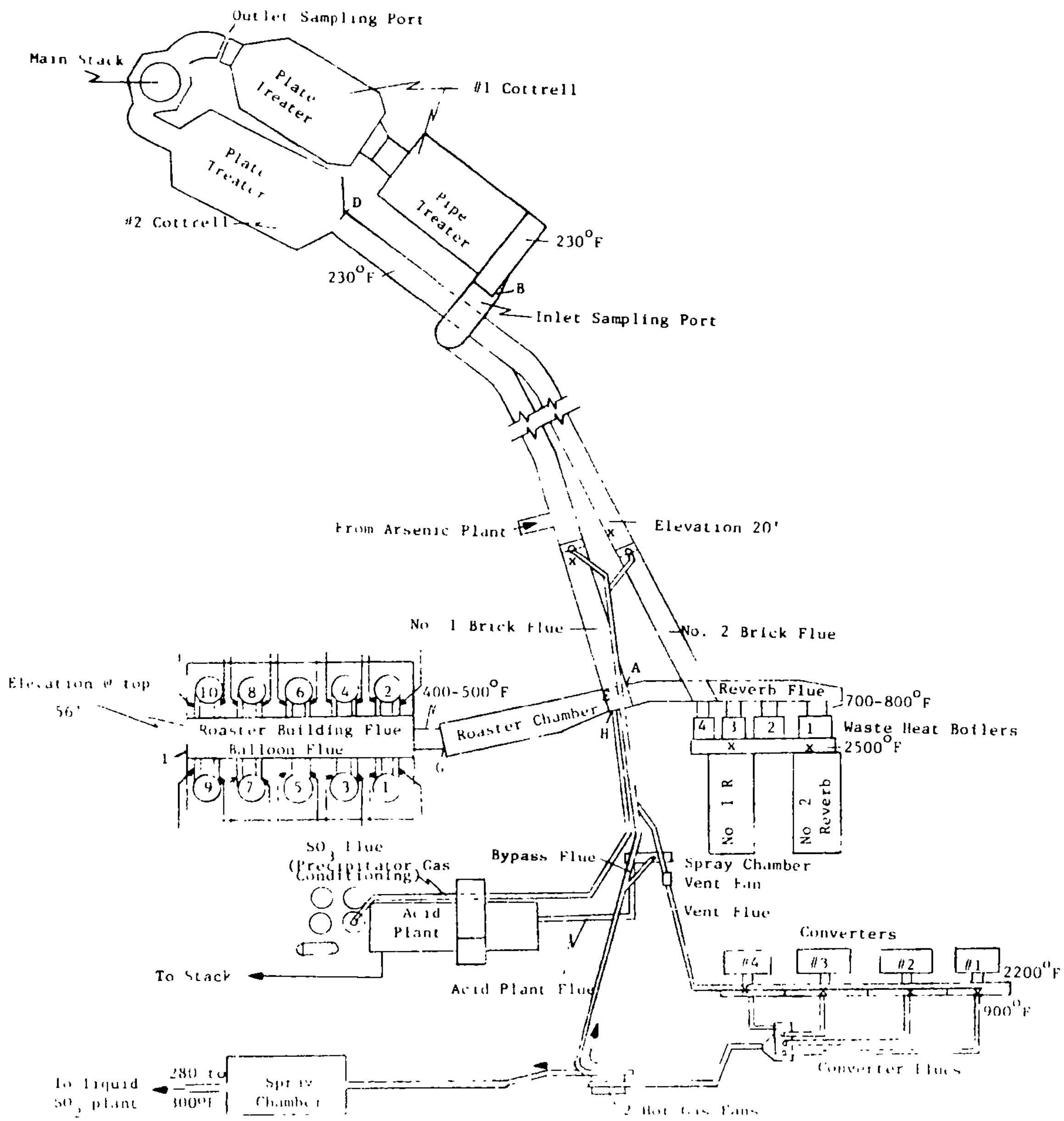
3. Current SO_2 Emission Control

The current nominal design level of sulfur recovery at Tacoma is a nominal 51%; on a consistent basis the plant achieves about 45-48% control, mainly because the gas streams are more dilute than originally assumed when the sulfur dioxide recovery system was designed. The plant practices supplementary control, i.e., when atmospheric dispersion is poor and ambient air SO_2 concentrations approach the standard, smelting is discontinued or reduced until meteorological conditions improve.

C. HISTORICAL RAW MATERIALS SUPPLY

Tacoma is a custom smelter and receives feed materials from many sources. The feed mix to Tacoma consists of concentrates, lead plant byproducts (i.e., matte and speiss), precipitates and scrap.

Table III-1 shows average feed compositions into Tacoma for the past several years. The overall composition of the smelter charge has not varied significantly for many years. Tacoma is one of the few processors of impure concentrates in the world and the only such processor in the U. S. who produces byproduct As_2O_3. Two of the concentrate sources for Tacoma--Lepanto and Northern Peru--provide high-impurity concentrates which are unacceptable in any reasonable amount to other smelters for metallurgical reasons. The same is true of lead plant byproducts (though they constitute a smaller stream in comparison). The low-impurity concentrates are acceptable to other smelters and the shipment of such concentrates to Tacoma is a matter of competitive smelting and refining charges and the



FLUE DIMENSIONS

Flue	L	H	W
No. 1 Brick Flue (A-B)	450'	24'	20'
No. 2 Brick Flue (C-D)	550'	24'	20'
Junction Tower (E)	26'	43'-4"	18'
Reverb Flue (G-H)	165-10"	20'-6"	27'
Roaster Building Flue (I-J)	120'	12'	12'-1"

Note. Roasters 1-6 10,000 SCFM/Roaster
Roaster 7-10 15,000 SCFM/Roaster

x Denotes Water Sprays

Source: Pacific Environmental Services, EPA-600/2-76-036K.

FIGURE III-2

GAS SYSTEM DUCTWORK AT TACOMA

TABLE III-1

MATERIALS FLOW TO SMELTER

(Percent)

SMELTER ASARCO, TACOMA	Approximate Annual Tonnage (1971-1973)	Cu	Fe	S	As	Sb	Pb	Zn	Bi	Se	Te	Sn	Ni
CONCENTRATES	273,603	26.2	23.6	35.2	4.2 (12.8 Max)	0.36 (1.85 Max)	0.67 (7.6 Max)	1.2 (5.8 Max)	0.05 (0.83 Max)	0.01 (0.03 Max)	0.02 (0.08 Max)		0.03 (0.6 Max)
LEAD PLANT BY-PRODUCTS													
Matte	6,039	41.76	5.06	16.57	1.19	0.50	9.15	2.67	–	0.082	0.061		0.04
Speiss (1)	11,144	59.84	0.58	0.68	17.25	8.83	8.70	0.10	–	0.007	0.008		0.70
Speiss (2)	30	59.16	0.80	0.30	11.47	6.70	10.20	0.14	–	0.027	0.048		3.80
PRECIPITATES	3,995 (C)	74.8	6.8	0.84	0.37	0.23	0.095	0.09	0.008				
HIGH GRADE SCRAP (PURCHASED)	10,308 (C)	96.0					0.2						
LOW GRADE SCRAP (PURCHASED)	1,079 (C)	71.0					2.35						
INHOUSE REVERTS	91,135	20.6	6.5	5.2	21.4	1.9	5.2	2.2	0.12				
AVERAGE SMELTER CHARGE		24.79	21.11	31.31	5.2	0.82	1.03	1.56	–	–	–		–
R – Reverbs C – Converters Ro – Roasters													

Source: Arthur D. Little, Inc., (October 1974), "The Economic Impact of New Source Performance Standards on the Copper Industry: An Assessment", Report to EPA.

availability of such services at Tacoma vs. other smelters. From Tacoma's viewpoint, some clean concentrates are a necessary component of the smelter charge to act as a diluent.

The various raw material inputs into Tacoma can be classified in several different ways:

- Sulfide-bearing materials (i.e., concentrates and lead plant by-products) vs. non-sulfide-bearing materials (i.e., precipitates and scrap).

- Low-impurity vs. high-impurity concentrates: The former can be treated at any smelter and Tacoma has to compete internationally for such concentrates, but Tacoma needs these to act as a diluent. On the other hand, Tacoma and the high-impurity concentrates are mutually interdependent since such concentrates cannot be smelted at other smelters in any reasonable amount.

- Imported materials vs. U. S. domestic materials: The major sources of imported materials are Northern Peru and Lepanto--located on Luzon in the Philippines. The bulk of the domestically mined materials come from the U. S. Southwest and a major fraction of this material (50-80% depending on the year) comes from the mines of Duval.

- Material from Asarco plants vs. other material: Northern Peru (100% owned by Asarco) and lead plant byproducts from East Helena lead smelter are Asarco-owned inputs. All others are not Asarco material. It should be noted that Asarco does not rely on Tacoma for smelting any significant portion of its domestic mine production.

- Material purchased on contract[1] vs. spot purchases or interplant transfers: The concentrates from Duval, Northern Peru and Lepanto fall into the former category. Tacoma will also process batches of "spot" concentrates (i.e., those purchased on a one-time basis) or other concentrates exchanged with or shipped from Arizona smelters when concentrate receipts in Arizona exceed smelting capacity.

D. THE NATURE OF CUSTOM AND TOLL SMELTING CONTRACTS; ITS INFLUENCE ON ASARCO'S ACCOUNTING SYSTEM

1. Custom and Toll Contracts

The terms "custom" and "toll" are used to describe the smelting (and usually refining) of concentrates produced by one firm at a smelter

[1]Tacoma's concentrate supply contracts have a contractual period of 3 years or less. The Japanese smelters have typically signed longer-term contracts with periods of 6 to 12 years.

and refining of another firm. In custom smelting, the concentrates are sold by the mining firm to the smelting and refining firm. In toll smelting, the smelting and refining firm provides these services to the mining firm and returns the recovered metals.

The transactions between a mining firm and a custom (or toll) smelter and refinery are covered by a contract called a "smelter schedule." Appendix A presents a typical example of such a schedule. Such schedules apply to concentrate deliveries not only to Asarco's smelters, but also Japanese and European smelters. Important features are as follows:

- In toll processing, the metal is returned after 90 days. In custom processing, concentrates are paid for based on prices prevailing 90 days after receipt of concentrates. As discussed below, this feature applies to Tacoma.

- In both custom and toll processing, the smelting and refining charge is quite insensitive to the price of copper. Because of this structure of the contracts, a toll smelter and refinery has revenues that are independent of the metal price. The same is true for custom processing as long as the metal is sold at the same time that the concentrates are paid for. These revenues, which reflect smelting and refining services, are referred to as "gross margin." As a result of this, any change in copper wirebar price directly affects the value of concentrate. The smelter and refining margin remains unchanged.

- When precious metals (gold and silver) are present in significant amounts, they are paid for or returned in a fashion identical to that described above for copper. Impurities such as arsenic, antimony, bismuth, lead, nickel, selenium and tellurium are penalized if present in significant quantities because their presence can cause metallurgical problems and can require additional processing.

- The contracts contain escalation clauses for changes in energy and labor rates. Thus, any cost increase resulting from changes in these rates can be passed on. Any cost increase resulting from increases in fuel use or from a productivity loss cannot be passed on.

This structure for smelting and refining charges evolved historically because a smelter operates efficiently (i.e., at minimum average total cost) at a little below rated capacity. Because of process bottlenecks, production above this point cannot be sustained for long without using large quantities of other factors of production, e.g., labor, maintenance materials, etc. On the other hand, the heat losses from any furnace are constant and essentially independent of output so that at low outputs, average energy costs at a smelter can increase dramatically. Given these constraints, smelters have been operated as service (low-risk) operations with a high rate of capacity utilization. Any benefits or disbenefits from fluctuations in metal prices have been reflected back to the mines who typically have more degrees of freedom for adjusting to changing market conditions.

2. Tacoma's Contracts

Three notable arrangements at Tacoma are those concerning: (1) Lepanto Consolidated Mining Company of the Philippines, which sends high-arsenic copper concentrate to Tacoma for smelting and refining (see Appendix D); (2) Northern Peru Mining (a wholly-owned Asarco company), which sends similar material via the Peruvian Government Marketing Agreement (see Appendix F); and (3) Duval Corporation (a subsidiary of Pennzoil Corporation) (see Appendix G), which is Asarco's single largest copper concentrate customer and provides clean concentrate. These three firms now account for about 65% of Tacoma's sulfur-bearing smelter feed.

We do not have in our possession copies of the contracts with these companies nor are we familiar with the exact contractual terms in force. All available information from diverse sources indicates that Tacoma's contracts with these three sources follow the features shown in Appendix A--features which are followed all over the world in contracts for copper concentrates. This evidence includes the nature of Asarco's accounting system, and the testimony of Simon D. Strauss, Executive Vice President of Asarco, Inc.[1]

Based on available information and professional judgement, we estimate Tacoma's smelting and refining charges for 1978 to be 22.7¢/lb copper.

We understand that the Lepanto and Northern Peru arrangements involve International Metals Company, a consolidated subsidiary, that is, Asarco purchases concentrates from these mines. In the case of Duval, concentrates from Duval's Battle Mountain mine are smelted and refined mainly at Tacoma, and additional material from the Sierrita mine and other Duval properties is also treated at Tacoma. Asarco, depending on the arrangements in force, may or may not have an ownership interest in all of these concentrates. For example, in 1976, approximately 52% of Duval's total copper production was toll smelted by Asarco and 25% was purchased by Asarco.[2]

The Lepanto contract signed in late 1976[3] is a three year contract renewable on option. The contract reportedly contains ceilings on smelter charges or on escalations based on world copper prices (LME prices) at any time.

---

[1] Simon D. Strauss, Testimony before OSHA re: Proposed Standard for Occupational Exposure to Inorganic Arsenic, September 9, 1976, p. 488 of Hearing Record Transcript.

[2] Pennzoil Company, 1976, Form-10K, p. 15.

[3] Metals Week (September 20, 1976), p. 3.

3. Tacoma's Accounting System

a. General Features

Asarco-New York, i.e., the parent company, treats Tacoma as a profit center for accounting purposes. This encompasses all of Tacoma's operations including smelting and refining services and byproduct sales.

Asarco's accounting system for Tacoma reflects all the characteristics of a toll smelter and refinery. The title to the major metals (copper, lead, zinc, gold and silver) is retained by the mine under a toll contract or by Asarco-New York for a custom contract. (All contracts are handled out of New York.) The gross revenues for the plant are smelting and refining charges adjusted for metal loss/gain during processing plus revenues from sales of byproducts such as arsenic trioxide, nickel sulfate, sulfuric acid, etc. Title to the byproducts rests with Tacoma.

While Tacoma's accounting system appears to treat byproducts as separate cost and profit centers, the costs of byproduct production are not fully allocated costs, and the smelting and refining operations bear the costs of separating impurities and byproducts. Copper thus bears the cost of removing arsenic until the arsenic-containing dusts are delivered from the arsenic collection system. The byproduct account starts at this stage and the costs of further treatment and marketing are borne by this account. Similarly, the precious metal account starts at the doré furnace, i.e., downstream of smelting and refining, and the nickel sulfate account starts after electrolyte purification. Also, costs are recorded as incurred and "profits" (sales of byproducts) are also recorded as incurred. Thus, the accounting system will show a loss when the byproduct is put into inventory or a large profit when extra material is sold out of inventory.

Tacoma returns the copper after 90 days, either to the mine under a toll contract or to Asarco-New York under a custom contract. The actual time for the metal in process is within ± 10 days of this amount. The impact of this difference, therefore, is relatively minor. On custom contracts there are some risks and benefits that accrue to Asarco-New York after 90 days.

The mines are paid 90 days after receipt of concentrates at prices prevailing at the time of payment. If Asarco is unable to sell this metal at the time of payment to the mines, Asarco-New York has to carry the metal in inventory. If at a later time this metal is sold at a higher price, a profit is realized by New York. Similarly, if this accumulated metal is sold at a lower price, a loss is realized by New York.[1]

---

[1] Simon D. Strauss, Testimony before OSHA re: Proposed Standard for Occupational Exposure to Inorganic Arsenic, September 9, 1976, p. 487 of Hearing Record Transcript.

b. Book Value

Our impression is that the gross book value of plant and equipment at Tacoma was approximately $46.7 million at December 31, 1975. Our understanding is that the net plant and equipment (after accumulated depreciation and amortization charges) at Tacoma was approximately $32 million at December 31, 1975.

c. Depreciation

Asarco uses the ADR Guidelines for equipment life allowed by the Internal Revenue Service as the basis for depreciation for tax purposes. For non-ferrous manufacturing operations, Asarco uses an 11-year life for acid plants, refineries, and smelters, and 9 years for chemical plants. Double declining balance (DDB) depreciation is taken for the first two years, and the Sum-Of-The-Year's Digits method (SOYD) is used for the remaining life. Table III-2 illustrates how this would work.

d. Investment Tax Credit

Asarco takes the Investment Tax Credit all "up front" as capital expenditures are made, i.e., at the presently allowable 10% of the amount of the investments, rather than spreading it over the life of the assets.

e. Corporate Overhead Allocation

Tacoma derives benefits from the parent company's financing and services for which it has been assessed an overhead allocation of about $2 million/year.

Asarco's policy has been to allocate general corporate administrative expenses (including interest on debt, research and development) among lines of business in proportion to the operating expenses attributable to such lines. Tacoma's share is about 7% of the total amount so allocated.

f. Shutdown Reserves

At March 31, 1976, Asarco carried reserves of $32 million on its balance sheet as liabilities to cover the anticipated losses to be incurred upon the closing of the Baltimore and Perth Amboy copper refineries and the Amarillo zinc plant. For Perth Amboy, some $10.5 million of the $20.5 million reserve was a current liability. We understand that the non-current portion of reserves represents in large part the present value of severance pay and additional pension benefits which must be paid when an actual plant shutdown occurs, as provided under union contract clauses. Tacoma's plant and equipment were carried on Asarco's books at about $32 million at year-end 1975. In contrast, Perth Amboy was carried at $7 million.

By comparison with Perth Amboy, we estimate that a Tacoma shutdown decision would involve an "unusual item" charge in Asarco's financial statements of approximately $40 million, pre-tax; which would become a reserve (less current charges for severance pay, plant write-off, etc.) to be drawn down over some 20 years subsequent to any shutdown. Actual payments would flow through Asarco's income statement year-by-year with a tax offset depending on the effective tax rate.

TABLE III-2

DEPRECIATION SCHEDULE

Depreciation Basis: DDB First Two Years - SOYD Remaining Life
(Figures below are in Percent of original cost)

	11 years Life		9 years Life	
Start Value	100.00	Remainder	100.00	Remainder
Year 1	18.18	81.82	22.22	77.78
2	14.88	66.94	17.28	60.49
3	13.39	53.55	15.12	45.37
4	11.90	41.65	12.96	32.41
5	10.41	31.24	10.80	21.60
6	8.93	22.31	8.64	12.96
7	7.44	14.88	6.48	6.48
8	5.95	8.93	4.32	2.16
9	4.46	4.46	2.16	0.00
10	2.98	1.49		
11	1.49	0.00		

Source: Arthur D. Little, Inc., estimates.

E. THE RELATIONSHIP BETWEEN TACOMA AND OTHER ASARCO PLANTS

Table III-3 shows the interplant flows between Tacoma and the other Asarco plants; namely, the East Helena lead smelter and the Amarillo copper refinery.

East Helena's byproducts contain copper, arsenic, antimony, lead and silver. The size of this stream is a function of the copper, arsenic and antimony intake at East Helena. Tacoma separates arsenic and copper away from the rest and returns a lead-rich converter fume to the lead smelter. The anode slimes from the Tacoma copper refinery are treated at Tacoma to produce doré (a mixture of gold and silver) and a slag containing selenium and tellurium. These streams are then treated at the Amarillo refinery to recover the metals.

Tacoma derives a margin (revenue) from treating the East Helena byproducts. Similarly, the other plants derive a margin from treating Tacoma's output streams. This margin, like the copper smelting and refining margin, is a treatment charge. We believe that Asarco's margin on precious metals is very small. This observation is based on many smelting contracts we have seen in the past where, for example, 98% of the gold in a concentrate is typically returned to the mine under a toll contract or is paid for under a custom contract at the full market price at the time of the transaction.[1,2] (A more detailed discussion of smelter schedules is presented in Appendix A.)

Similarly, we believe that the margin on selenium and tellurium is also small and selenium and tellurium processing is not always profitable. This observation is based on the fact that contracts for blister containing selenium and tellurium typically contain a profit/loss sharing clause where the shipper benefits from, or is penalized for the selenium and tellurium content.

In the past, Tacoma treated about 20,000 tons/year of blister copper from the Hayden smelter in the Tacoma refinery. After commissioning of the Amarillo refinery, this blister is being treated at Amarillo. This appears to be a logical, cost-minimizing strategy for the following reasons. In electrolytic refining, labor costs are usually a larger component of total costs than electricity costs. A large automated and modern plant like Amarillo would have a much higher productivity than an older, smaller plant like Tacoma. Thus, for the future, we expect the Tacoma refinery to treat only the smelter output from Tacoma.

Asarco has constructed an antimony plant at El Paso which will treat copper-silver-antimony-arsenic containing concentrates by a hydrometallurgical process. This plant is expected to come on-stream in 1977. Once this

---

[1] It should be noted that net margins from copper smelting and refining and from precious metal treatment are usually not treated separately even for accounting purposes.

[2] Simon D. Strauss, op. cit., p. 473.

TABLE III-3

INTERPLANT FLOWS TO AND FROM TACOMA

Item	Characteristics	Average Size of the Stream per Year
To Tacoma		
E. Helena Matte and Speiss	52.8% Cu; 9.7% Pb 1.7 oz/ton Au; 236 oz/ton Ag	12,000 tons
From Tacoma		
Nitre Slag to Amarillo	contains Se and Te	200 tons
Doré to Amarillo	1.1% Au; 97.2% Ag	11,000,000 oz
Converter Dust to E. Helena	0.2% Cu; 0.4% Pb; 1.3 oz/ton Ag	35,000 tons

Source: Arthur D. Little, Inc. estimates, based on Asarco data.

plant is operating, East Helena will no longer smelt these concentrates. This would decrease the size of the byproduct stream to Tacoma.

If Tacoma were to close, Asarco would lose revenues from smelting and refining services and from byproduct sales. Table III-4 shows typical byproduct production at Tacoma. We would expect the arsenic production to decrease after the antimony plant is on-stream. We have used an estimate of 10,000/year of As_2O_3 production in the base case for the impact analysis. Other byproducts would remain the same except for sulfur derivatives which would increase with different levels of incremental pollution control.

Lepanto and Northern Peru would have to close until an alternative outlet such as the Philippine smelter became available. Duval and other producers of clean concentrates would seek smelting and refining services from other smelters in this country and abroad and/or consider alternatives such as hydrometallurgical processing.

As far as the other Asarco plants are concerned, the major loss would be in the ability to treat the East Helena matte and speiss. Asarco, with the construction of the antimony plant at El Paso, has already taken the first step to reduce the copper-silver-antimony-arsenic intake into East Helena, and reduce the size of the recycle stream. This reduced stream might be small enough to be blended with the feed at Hayden or El Paso without any equipment changes. Under these conditions, the arsenic would be enriched in the roaster and reverb dusts. A portion of this dust might have to be bled from the system from time-to-time and stockpiled. If this proves infeasible, the next step would be the construction of roasting facilities at El Paso to handle these flue dusts. A Godfrey roaster (for arsenic recovery) is a relatively small piece of equipment and the building of such a roaster (plus the necessary particulate control facilities) at El Paso could probably cost perhaps $5-10 million. However, we do not know whether the regulatory environment would permit this type of construction.

There is also evidence in the technical literature[1] to suggest that East Helena byproducts could be treated by a hydrometallurgical process very similar to that employed in the antimony plant. The East Helena byproducts contain metals valued at $23-25 million/year. Based on the discussion above, we believe that the stockpiling of these byproducts in the event of a Tacoma shutdown is a remote possibility.

Finally, a Tacoma shutdown will result in underutilization of Amarillo's capacity for doré refining and selenium/tellurium recovery.

[1] Gerlach and Pawlek, "Pressure Leaching of Speiss" in Unit Processes in Hydrometallurgy, Gordon and Breach Science Publishers, (1963), pp. 308-325.

TABLE III-4

TYPICAL BYPRODUCT PRODUCTION AT TACOMA

Crude Arsenic Trioxide	95% pure	7,000 tons
Refined Arsenic Trioxide	99% pure	4,000 tons
Metallic Arsenic	---	200 tons
$NiSO_4$	26.2% Ni	900 tons
H_2SO_4	93% acid	50,000
Liquid SO_2	---	35,000

Source: Arthur D. Little, Inc. estimates, based on Asarco data.

IV. BASELINE CONDITIONS

A. INTRODUCTION

The baseline conditions represent expected operations at Tacoma in 1978 and beyond in the absence of incremental expenditures for additional SO_2 control or for proposed OSHA standards for inorganic arsenic. These baseline conditions provide a point of reference from which comparisons can be made. The baseline conditions are here defined, as a minimum, to include the following points: (a) Basic microeconomic characteristics of the market in which Asarco-Tacoma operates, (b) outlook for smelter capacity and forecasts of copper prices, (c) Tacoma's production capacity and raw materials supply for 1978 and beyond, and (d) production costs and revenues (including byproduct revenues) at Tacoma.

Section E of Chapter V summarizes how the various aspects of the baseline conditions presented here are used in the impact analysis.

B. BASIC MICROECONOMIC CHARACTERISTICS OF THE MARKET IN WHICH ASARCO-TACOMA OPERATES

For the purposes of our analysis, the relevant market in which Asarco-Tacoma operates is defined as the exchange or sale of a service, namely smelting and refining, where on the seller side we have Asarco-Tacoma and on the buyer's side we have, principally, producers of low impurity of "clean" concentrates (i.e., Duval and others), producers of high impurity or "dirty" concentrates (i.e., Lepanto, Northern Peru, East Helena matte and speiss) and suppliers of scrap and precipitates.

On the sellers' (or supply) side, Tacoma's basic potential competition consists of the Japanese smelters and the new Philippines smelter expected to come onstream at the beginning of 1981, under the general "state of the world" assumption of a domestic smelter capacity constraint over the next five to seven years. On the buyer's side, most of the principal suppliers mentioned are quite dependent on Tacoma, at least in the short-run, as a minimum for technical reasons (i.e., the high impurity content). If microeconomic theory is generally to be used as a conceptual guide, such a market can be characterized as one having certain key features of bilateral oligopoly.

The concept of bilateral oligopoly would suggest that both sides (i.e., Tacoma and its customers) exercise considerable market power. A closer analysis indicates, however, that while such a perception may be largely correct as a first approximation, it tends to overstate the market power actually enjoyed by Asarco-Tacoma or by its various suppliers. Asarco-Tacoma, would, theoretically, be able to exercise market power over particularly the 1978-1980 period. However, as discussed below in some detail, Tacoma's market power is not only limited even in the short-run but is also highly dependent on copper prices. This means it would be risky for Tacoma to try and take advantage of its perceived market power, by following a discriminatory monopolistic pricing strategy based on an expected or ex ante copper price level over which it has no control. Should the expected copper price level prompting such action not in fact materialize, the smelter, having charged the mines to the limit, may end up facing a disastrous situation if the mines decide, for example, to shut down, not being able to recover even their variable costs. This may explain, in part, why Tacoma and other smelters have historically been reluctant to exercise their presumed market power, in the sense just described. Nevertheless, the microeconomic discussion presented below explores the theoretical "decision space" available to the various participants, over the short-run as well in the longer-run, and the constraints influencing their decisions. This serves to illustrate the degree of interdependence of the various participants in the relevant market in which Asarco-Tacoma operates and provides the needed "market structure" background used in our impact analysis.

1. Short-run Demand Conditions Facing Asarco-Tacoma

The demand functions facing Asarco-Tacoma in the short-run, as well as in the long-run, are shown in Figures IV-1 and IV-2, in terms of Tacoma's three major groups of customers (i.e., suppliers of "clean" concentrates, "dirty" concentrates, and scrap and precipitates).

We will proceed to discuss the short-run and long-run demand conditions under which Asarco-Tacoma is most likely to operate over the relevant period. The short-run discussion will first consider conditions under which domestic smelter capacity is constrained and available excess capacity exists in Japan. We will then show how the demand conditions facing Tacoma would differ, if at all, under conditions of smelter capacity constraints both in the U. S. and Japan.

a. Suppliers of "Clean" Concentrates

(Principally Duval plus others; we will use Duval as a surrogate for this group of Tacoma's customers): price elasticity of demand[1] is zero (i.e., $e_p = 0$, demand is perfectly inelastic), over the smelting/refining price range (at Tacoma) between zero and p_1, with $q_1 = 46{,}500$ short tons/year of production of contained metal (Duval: 26,100 short

---

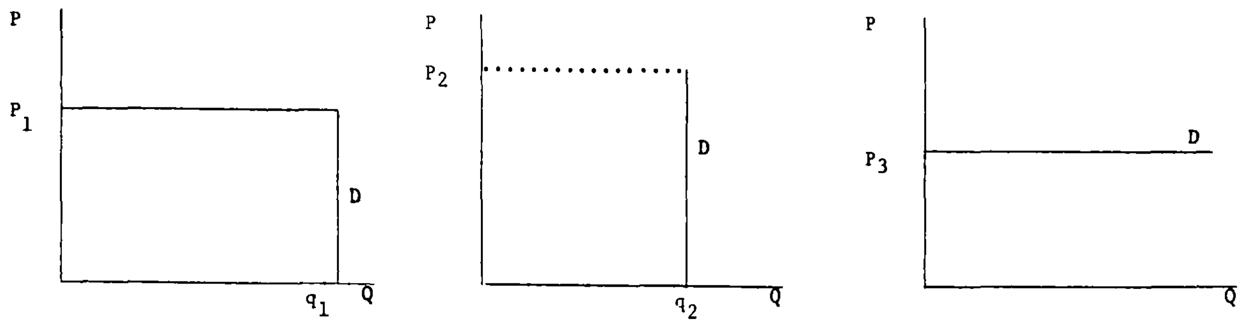
[1]Defined, for our purposes here, as "point elasticity of demand", which measures the proportionate change in the quantity demanded resulting from a proportionate change in price:

$$e_p = \frac{dq}{q} / \frac{dp}{p}$$

FIGURE IV-1

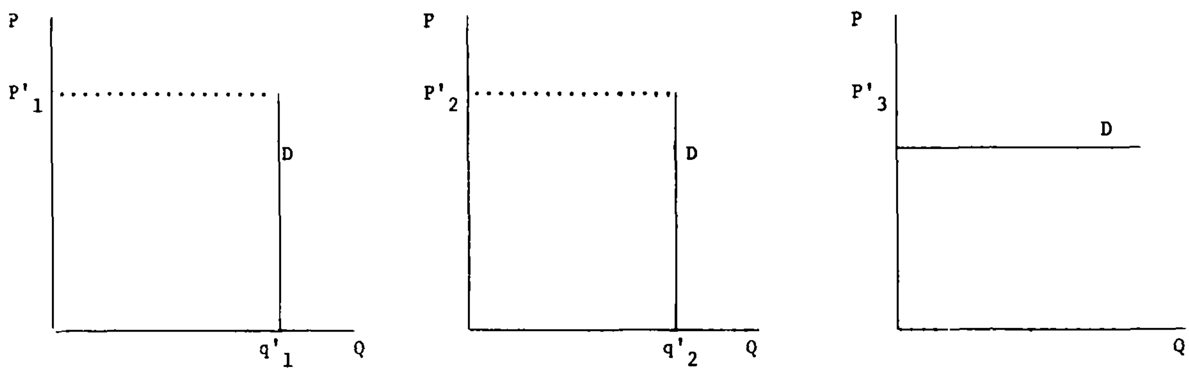
DEMAND FUNCTIONS FACING ASARCO-TACOMA IN THE SHORT-RUN[a,b]

A. Short-run demand functions facing Tacoma under conditions of domestic smelter capacity constraints and available excess capacity in Japan.



(1) "clean" concentrates (2) "dirty" concentrates (3) scrap and precipitates

B. Short-run demand functions facing Tacoma under conditions of domestic smelter capacity constraints and no excess capacity in Japan.



(1) "clean" concentrates (2) "dirty" concentrates (3) scrap and precipitates

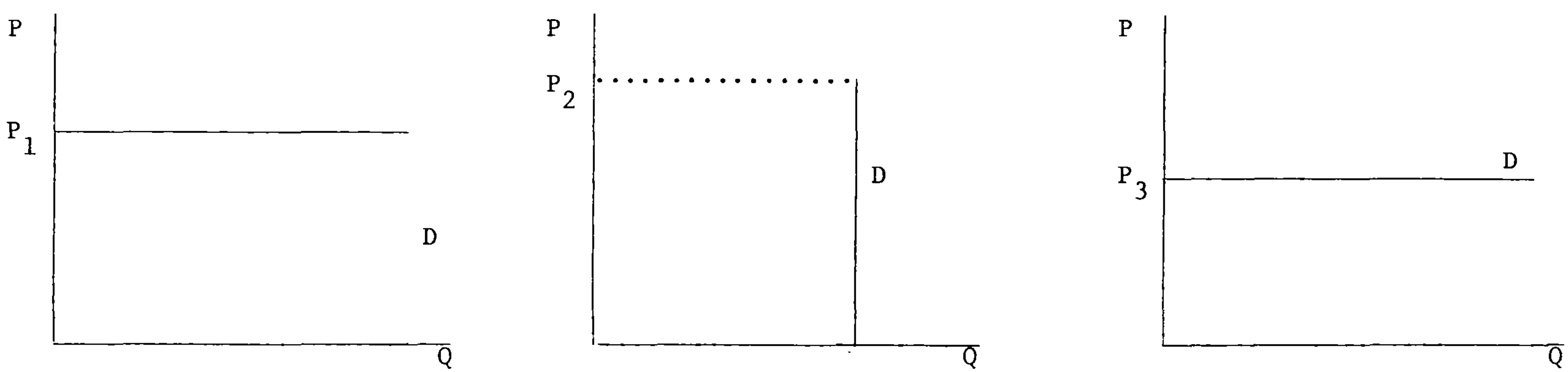
---

Notes: a. These demand functions depict demand conditions expected to prevail in any typical year over the period 1978-1981.

b. Discontinuities in demand functions shown by dotted lines indicate potential mine closure beyond a smelting/refining price level charged by Asarco-Tacoma, given prevailing copper prices (see text).

FIGURE IV-2

DEMAND FUNCTIONS FACING ASARCO-TACOMA IN THE LONG-RUN[a,b]



(1) "clean" concentrates (2) "dirty" concentrates (3) scrap and precipitates

Notes: a. "The long-run" is defined here to refer basically to the post-1981 period; the new Philippines smelter to come on-stream at the beginning of 1981.

b. Discontinuities in demand functions shown by dotted lines indicate potential mine closure beyond a smelting/refining toll rate charged by Asarco-Tacoma, given prevailing copper prices (see text).

tons/year; others 20,400 short tons/year). At p_1, the demand schedule becomes discontinuous and perfectly elastic ($e_p = \infty$), since at p_1 Duval (i.e., "clean" concentrate suppliers) would be indifferent between Tacoma and Japan and would shift to Japan at Tacoma prices in excess of p_1. Our estimate of p_1 is 27.5¢/lb. (in 1978 prices), which defines the estimated "trigger" point for Duval and other Southwestern suppliers of clean concentrates, derived as follows:

$$p^T + c_1 \leq p^J + c_2 + d$$

where (¢/lb; in 1978 prices):

p^T: smelting/refining charge at Tacoma (cents per pound of copper content);

c_1: weighted average transportation cost from Battle Mountain and the Southwest (e.g., Sierrita) to Tacoma, estimated at 3.5¢/lb;

c_2: weighted average transportation cost to Japan from Battle Mountain and the Southwest, estimated at about 5¢/lb;

d : "distress payment" to Japanese smelters, for accommodating foreign concentrates, estimated at about 4¢/lb;

p^J: the average smelting/refining charge at Japanese smelters, estimated at 22¢/lb;

then,

$$p^T + 3.5¢/\text{lb} \leq 2.20¢/\text{lb} + 5.0¢/\text{lb} + 4.0¢/\text{lb}$$

$$p^T \leq 22.0 + 5.0 + 4.0 - 3.5$$

$$p^T \leq 27.5¢/\text{lb}$$

Thus p^T must be less than or equal to 27.5¢/lb, as a condition for Duval and the other Southwestern suppliers of class concentrates not to shift to Japan.

The sale of concentrates under "abnormal" conditions is usually referred to as a "distress" sale. The U. S. mines have sold batches of concentrates under such conditions typically during strikes (e.g., 1967, 1971, 1974, etc.) when the U. S. smelters were shutdown and concentrates were available from inventory. We understand that concentrates from major Southwestern mines such as Twin Buttes and Duval have been sold to Japanese smelters. Such concentrate sales are labeled "distress" sales since the mine is usually willing to accept a lower-than-normal netback in order to sell the concentrates and offer the purchaser (smelter/refinery) additional profit as an incentive to purchase these "distress" concentrates.

Depending on short-term cpacity utilization and concentrate supply situation, we would expect this incremental "distress" payment to vary a great deal. We do not have in our possession contracts governing such sales. We believe the normal smelter/refinery profit on smelting and refining services is about 5% of margin or about 1¢/lb. In comparison, an incremental "distress payment" of 4¢/lb used in this report represents "extraordinary" profits to the smelter/refinery of 20% and is, in our view, an upper bound for such payments. The estimated Japanese smelting/refining costs are detailed in Appendix I. The various transportation cost estimates used here, including those employed below, are detailed in Appendix J.

In this context one has to examine whether or not the Japanese smelters can accommodate, for example, Duval. The clean concentrates smelted at Tacoma amount to 46,500 tons/year. This is about 5% of Japanese capacity. In demand-slack periods, when copper prices are depressed and capacity utilization is low, the concentrates could be accommodated and Duval would have a maximum inducement to switch. In a demand-crunch period, the concentrates could probably still be accommodated but, because of tight capacity conditions, a higher distress payment may be required.

b. Suppliers of "Dirty" Concentrates

(Consisting of Lepanto, accounting for 19,200 short/tons year of contained metal output at Tacoma; Northern Peru with 5,760 short tons/year; and East Helena 6,600 short tons/year): demand is perfectly inelastic over a smelting/refining price range at Tacoma between zero and p_2, with q_2 at 31,560 short tons/year. At p_2, the demand schedule becomes discontinuous and perfectly elastic, since at p_2 the mines would theoretically be indifferent between staying with Tacoma and closing down; at p_2 the mines would be barely covering their average variable costs and would hence be at the verge of a shut-down decision. At smelting/refining charges at Tacoma plus transportation costs exceeding p_2, the mines would in all likelihood decide to shut down.

Of course, the level of p_2 would depend largely on the prevailing copper prices. The maximum toll rate(s) that Tacoma can charge the various mines can be derived from the following inequality:

$$p^{cu} - (p_i^T + c_i) \geq c_i^{avc} \quad \text{or} \quad p_i^T \leq p^{cu} - c_i - c_i^{avc}$$

where (¢/lb; in constant 1978 prices):

p^{cu} : price of copper;

p_i^T : smelting/refining charge at Tacoma for mine/mill i (i = 1, ..., m);

c_i : estimated transportation cost from mine/mill i (i = 1, ..., m) to Tacoma;

c_i^{avc}: estimated average (unit) operating and maintenance costs (i.e., average variable costs) at mine/mill i (i = 1, ..., m), where operating and maintenance costs are defined to include estimated required interest payments.

This inequality says that at a given copper price, Tacoma will charge the mine as high as possible but just short of causing the mine to shutdown (i.e., the mine is barely able to cover its variable costs, including estimated required interest payments).

As discussed in Chapter III, Asarco has several potential alternatives to treat the East Helena byproduct stream within its other plants. (The size of this stream will also decrease after the antimony plant in El Paso starts up in 1977.) For analytical convenience, we have treated East Helena byproducts to be equivalent to the other impure concentrates from Lepanto and Northern Peru. This note concerning our analytical treatment of East Helena holds for all subsequent discussions pertaining to East Helena given in this chapter or in Chapter V.

c. Suppliers of Scrap and Precipitates

The demand function facing Tacoma on the part of the suppliers of scrap and precipitates is perfectly elastic ($e_p = \infty$) at p_3 = 22.7¢/lb. This is a clearcut instance where Tacoma is a price-taker, not a price-setter, as many other firms (e.g., secondary smelters) are able to provide the needed services. (See Appendix K.) This means that if Tacoma raises its smelting/refining charges for this group of its customers above about 23¢/lb, it will quite likely run the risk of losing them.

The short-run demand conditions just described, in terms of the demand functions (and elasticities) facing Tacoma, assuming domestic smelter capacity constraints and availability of excess capacity in Japan, might be altered as follows if we now assume capacity constraints both in the U. S. and Japan:

- No significant changes are likely to take place concerning the demand functions facing Tacoma from the suppliers of "dirty" concentrates and from the suppliers of scrap and precipitates.

- The demand function facing Tacoma from Duval (i.e., all suppliers of "clean" concentrates) would be, as before, perfectly inelastic over a given smelting/refining charge at Tacoma between zero and p_1' (refer to Figure IV-1.B), where p_1' is a function of the prevailing domestic producers' refined copper prices, p_t^{cu}, such that Tacoma would potentially force the mines into closure if the following conditions hold:

$$p_t^{cu} - (p_{it}^T + c_i) \leq c_{it}^{avc}$$

where the terms are as defined before, and

$$p^T_{it} + c_{it} \geq p^o_t + c_{jt}$$

where

p^o_t : average smelting/refining charges at other smelters in year t, in 1978 dollars, to which the mines could shift; and,

c_{jt} : transportation cost(s) from each mine to other smelters.

2. Long-run Demand Conditions

Long-run demand functions facing Tacoma from the three major groups of suppliers are shown in Figure IV-2 and discussed below:

a. Suppliers of "Clean" Concentrates

The demand function is perfectly elastic at a given smelting/refining cost (including transportation cost), p_1, above which Duval (i.e., Tacoma's largest single supplier of "clean" concentrates) would decide to build its own smelter. For a discussion of the economics of a new smelter in the Southwest refer to Appendix H. Our estimate of the smelting/refining cost at such a new smelter is 33-35¢/lb (in 1978 prices).

Duval's total mine production of copper is about 135,000 tons/year of copper. This is large enough to be smelted in an average-size flash smelter and by utilizing flash smelting and conventional refining, Duval could smelt and refine its entire mine output for 33-35¢/lb. We understand that Duval's CLEAR process, which treats sulfide concentrates hydrometallurgically, might have costs in about the same range. Duval has built a 40,000 ton/year CLEAR plant. The plant is expected to reach its design operating rate in 1977 at which time the production costs of the process would be defined better.

The transportation costs for Duval in shipping its concentrates to a single Arizona location (near its largest mine) would be about 1¢/lb and the cost to Duval of this approach would be 33 to 35 + 1 = 34 to 36¢/lb. The Tacoma smelting charge which would induce them to move in this direction is 34-36¢/lb <u>less</u> the transportation charge of 3.5¢/lb. This is 30.5-32.5¢/lb or an average of 31.5¢/lb.

b. Suppliers of "Dirty" Concentrates

The short-run discussion of demand conditions is equally applicable here, with one major exception: Lepanto's long-term options and the implications of the new Philippines smelter which is discussed in Appendix E.

Northern Peru and East Helena: With the potential (planned) availability of a new ocean-front smelter in the Philippines as of the beginning of 1981, with enough extra capacity to accommodate both Northern Peru and (in principle) East Helena, the maximum charge that Tacoma could exact (in the case of Northern Peru) can be estimated from the following inequality which defines Northern Peru's "trigger" point, effective after 1980:

$$p^T + c_3 \lesseqgtr p^P + c_4$$

where (¢/lb; in 1978 prices):

p^T : smelting/refining charge at Tacoma;

c_3 : transportation cost from Northern Peru (Quiruvilca Mine) to Tacoma (estimated at 3¢/lb);

p^P : smelting/refining charge at the new Philippines smelter (estimated at 33.0¢/lb);

c_4 : transportation cost from Northern Peru (Quiruvilca Mine) to the new ocean-front Philippines smelter (estimated as 3.0¢/lb).

Since c_3 and c_4 fall out (i.e., $c_3 = c_4$), we have $p^T \lesseqgtr p^P$ (i.e., p^T cannot exceed 33.0¢/lb). We can assume, to simplify matters, that this boundary condition also holds for East Helena.

What next remains to be demonstrated is that at p^T = 33.0¢/lb, Northern Peru and East Helena will stay in business. The necessary condition is given by

$$p_t^{cu} - (p_t^T + c_3) \gtrsim c_t^{avc}$$

where the terms are as defined before and c_t^{avc} is the average variable costs at Northern Peru (and East Helena), including required interest payments. The sufficient, long-term, condition is given by the same inequality, except that the c_t^{avc} on the right-hand side is replaced by c_t^{atc}, which is the average total cost of Northern Peru (and East Helena), including a "normal" rate of return on investment.

Lepanto: The Lepanto-Tacoma relationship presents a special case, with certain complications, discussed in detail in the next chapter (refer to Sections D and G). It should suffice to identify here only the conditions under which Lepanto would continue supplying Tacoma after 1980. The necessary, but not sufficient, condition for this to happen is given by

$$p_t^T + c_5 \lesseqgtr p_t^P + c_6$$

where (¢/lb; in 1978 prices):

p^T : smelting/refining charge at Tacoma;

c_5 : transportation cost from Lepanto to Tacoma (estimated as 3.0¢/lb);

p^P : smelting/refining charge at the new Philippines smelter (estimated as 33.0¢/lb);

c_6 : transportation cost from Lepanto to the new Philippines smelter (estimated as 1.0¢/lb).

We can hence solve for p^T as follows:

$$p^T + 3.0¢/lb \leq 33.0¢/lb + 1.0/lb$$

$$p^T \leq 33.0 + 1.0 - 3.0$$

$$p^T \leq 31.0¢/lb$$

The sufficient condition would have two versions, weak and strong.

Weak version:

$$p_t^{cu} - (p_t^T + c_5) \geq c_t^{avc}$$

and/or

$$p_t^{cu} - (p_t^P + c_6) \geq c_t^{avc}$$

where the terms are as defined before; c_t^{avc} refers to Lepanto's average variable costs (defined to include required interest payments).

Strong version:

$$p_t^{cu} - (p^T + c_5) \geq c_t^{atc}$$

and/or

$$p_t^{cu} - (p^P + c_6) \geq c_t^{atc}$$

where

c_t^{atc} is total unit costs (average total cost) at Lepanto, in year t, for both the mining and milling stages of production (f.o.b. mill). Average total cost equals the sum of average variable cost and average fixed cost at each given level of production; over the entire range of production, the average total cost (ATC) function of a firm (industry) is typically described, for pedagogical purposes, as U-shaped.

c. Suppliers of Scrap and Precipitates

Their demand function for Tacoma's services is perfectly elastic, as discussed before, at about 22.7¢/lb. Hence, the earlier discussion holds here.

3. Short-run and Long-run Market Conditions for Asarco-Tacoma: Conclusions

We have earlier characterized the relevant market in which Asarco-Tacoma operates, in quite general terms, as one having key features of bilateral oligopoly. In such markets, both buyers and sellers are said to possess market power, such that there exists no unique equilibrium price-output solution. In other words, the price-output solution in a market with bilateral oligopoly (oligopoly-oligopsony) features is essentially indeterminate. Gaming or bargaining is very quickly introduced into the picture, with each bargain being possibly influenced by the previous one.

In the present case, a few buyers (i.e., mines producing "clean" concentrates, "dirty" concentrates, and suppliers of scrap and precipitates) face at least two sellers, one of which is Asarco-Tacoma. Although both sides would appear to possess market power, particularly in the short-run, a clear examination of the possible options open to the various participants indicates that Asarco-Tacoma can in fact exercise quite limited market power. Beyond certain well-defined price levels Tacoma may want to charge, the suppliers would find it advantageous to seek alternative arrangements, if not immediately certainly within a few years.

Our basic conclusions can be summarized as follows:

a. Short-run

In the short-run, at a Tacoma price in excess of 27.5¢/lb, (in 1978 dollars), Duval and other Southwestern mines, presently supplying "clean" concentrates to Tacoma (i.e., accounting for 46,500 short tons/year of Tacoma's production of contained metal, representing 46.5% of its total output and 59.6% of its output from sulfur-bearing materials), would in all likelihood switch to Japanese smelters. This trigger point does take into account that the mines involved would quite likely have to make a "distress payment" to Japanese smelters to accept these concentrates. This represents the first-line of defense that the "clean" concentrate mines would be expected to exercise, in the short-run, against price increases at Tacoma. Nevertheless, with domestic smelter capacity constraints, Tacoma could "pass on" to this group of its customers a modest portion of its cost increases in real terms (i.e., no more than a few cents/lb).

b. Long-run

Over the longer-run the switch to Japanese smelters would still be triggered at a 27.5¢/lb price at Tacoma. In addition, at Tacoma prices above roughly 31.5¢/lb, Duval would find it attractive to build a new smelter. Given the fact that Duval at present (1978 base conditions) accounts for about 26% of Tacoma's total output and 33% of Tacoma's output from sulfur-bearing materials, Duval's departure would almost certainly threaten Tacoma's economic viability.

It should be noted, in this connection, that if Duval follows this option, it would not be "safe" for Asarco-Tacoma to assume that Duval can necessarily be replaced by other mines, for two basic reasons.

(1) If Duval were to build its own minimum efficient-size smelter (i.e., about 100,000 short tons/year of output of contained metal), it would in all likelihood discontinue its current shipments to Asarco's El Paso and Hayden facilities. This would, in turn, create a smelter capacity slack which would have "first call" on any overflow concentrates, which might otherwise be diverted to replace Duval at Tacoma.

(2) Over most of the impact analysis period in question (post-1984 period), new smelter capacity expected to come on-stream, most probably located in the Southwest, would render hazardous such an expectation or assumption.

c. Suppliers of Scrap and Precipitates

The suppliers of scrap and precipitates have a perfectly elastic demand schedule for Tacoma's services. Hence, at Tacoma prices in excess of 22.7¢/lb (in 1978 dollars) Tacoma would risk losing this group of its customers. This condition would hold both in the short-run and in the long-run.

d. Suppliers of "Dirty" (High-Impurity) Concentrates

The suppliers of "dirty" (high-impurity) concentrates, with perfectly inelastic demand schedules (at least over the short-run), are in the least favorable position, in terms of any "cost pass on" by Tacoma. They would have to absorb a higher share of any increase in Tacoma's real costs on a per unit basis (i.e., not necessarily a larger absolute share of total increment in Tacoma's real costs, since these mines account for only 40% of Tacoma's output from sulfur-bearing materials). At any rate, the price increase on a per unit basis (cents/lb) which these mines could absorb in the short-run, will depend on the absolute level of copper prices at any time. In the longer-run (i.e., after 1981), they can switch to the new Philippines smelter. Under certain conditions, Lepanto may find it advantageous to supply both Tacoma and the new Philippines smelter after 1980.

C. OUTLOOK FOR COPPER PRICES

The long-term outlook for domestic copper prices over the period 1978-1995 covered in this study basically depends upon the long-run cost of copper production which allows a normal rate of return on invested capital, the growth in demand conditioned by the pace of macroeconomic growth, relative prices of other products which are substitutable for copper (e.g., aluminum), as well as on international economic developments affecting the demand for and the supply of copper and copper substitutes in the rest of the world. These long-run factors include, also, the combined effects of pollution control costs and constraints on capacity growth imposed by pollution control regulations. Domestically, for example, the U. S. copper industry is expected to face smelter capacity constraints until about 1983-1985. These constraints are a result of the way in which the Tall Stack Guidelines and the New Source Performance Standards (including the modification and reconstruction provisions) interact to prevent small increments of capacity at existing smelters.

The impact of federal air pollution regulations on the U. S. copper industry is currently being examined in another study by Arthur D. Little, Inc., under contract with the U. S. Environmental Protection Agency.[1] Preliminary analyses, using an econometric simulation model of the U. S. copper industry developed as part of this study shows that compliance costs associated with domestic federal air pollution regulations, combined with the constraints on capacity growth imposed by these regulations, will result in higher domestic prices for copper and increased imports over the period 1978-1995 compared with what would be expected under alternative sets or combinations of hypothesized baseline conditions. The final results of this analysis are not yet available for inclusion in this report.

However, for illustrative purposes only, preliminary results on domestic copper prices under two different sets of baseline conditions have been tabulated in Table IV-1. These forecasts are somewhat optimistic in that they reflect relatively high LME price assumptions.

It should be noted that these forecasts represent interim results only, developed in connection with the study for EPA just noted and do not necessarily represent our final estimates that we expect will be contained in our forthcoming final report to EPA on this study.

D. TACOMA'S PRODUCTIVE CAPACITY AND RAW MATERIALS SUPPLY FOR 1978 AND BEYOND

1. Productive Capacity

Tacoma's productive capacity has undergone several changes since the early 1970's. These changes are discussed below since they determine Tacoma's future capacity under the baseline and alternative pollution

[1]Refer to Arthur D. Little, Inc. (ADL), Economic Impact of Environmental Regulations on the U. S. Copper Industry, draft report submitted to U. S. Environmental Protection Agency (EPA), under Contract No. 68-01-2842 (October, 1976).

TABLE IV-1

FORECASTS OF DOMESTIC COPPER PRICES UNDER ALTERNATIVE MACROECONOMIC GROWTH SCENARIOS, 1978-1985[a]

Description	1978	1979	1980	1981	1982	1983	1984	1985
(In 1974 prices, ¢/lb)								
MACRO I[b]	78.6	80.8	80.4	82.7	84.4	82.3	85.3	84.2
MACRO II[c]	67.6	67.5	69.2	69.2	69.5	68.5	69.3	69.1
(In 1978 prices, ¢/lb)[d]								
MACRO I[b]	104.6	107.5	107.0	110.1	112.3	109.5	113.5	112.1
MACRO II[c]	90.0	89.8	92.1	92.1	92.5	91.2	92.3	92.0

Notes and Sources:

a. These forecasts are derived from the Econometric Simulation and Impact Analysis Model of the U. S. Copper Industry developed by Arthur D. Little as part of a study of the economic impact of federal air pollution control regulations on nonferrous industries, with primary emphasis on the U. S. copper industry, under Contract No. 68-01-2842.

Refer to Arthur D. Little, Inc. (ADL), Economic Impact of Environmental Regulations on the U. S. Copper Industry, draft report submitted to the U. S. Environmental Protection Agency (EPA), under Contract No. 68-01-2842 (October, 1976).

b. Reflects a relatively high macroeconomic growth scenario for the United States over the 1976-1985 period, with 80¢/lb LME copper prices in the 1980's (in constant 1974 prices).

c. Reflects a low macroeconomic growth scenario for the United States, with 80¢/lb LME copper prices in the 1980's (in constant 1974 prices).

d. Expressed in 1978 prices by using the Wholesale Price Index (WPI) for industrial commodities:

	(1967 = 100.0)	% Change per Year		(1974 = 100.0)
1974	153.8	-		100.0
1975	171.5	1974-1975:	11.5	111.5
1976	182.3	1975-1976:	6.2	118.5
1977 (assumed)	-	1976-1977:	6.0	125.6
1978 (assumed)	-	1977-1978:	6.0	133.1

Source: Survey of Current Business (October, 1976), pp. S-8, S-9; also, May, 1977, p. 5-9.

control scenarios.

The Tacoma smelter has employed professional meteorologists since 1969 for SCS (production curtailment during adverse weather). This SCS approach, after an initial learning period, reached the limit of its effectiveness in 1972 for meeting national ambient air quality standards (NAAQS) and in 1973 for meeting local standards. The SCS system is able to meet NAAQS most of the time. The local standards are still violated and the number of violations reached a constant level starting in 1973. Until 1974 only about 17% of the input sulfur was being recovered in the acid plant. The addition of the liquid SO_2 plant in 1974 increased the constant emission control from 17 to about 48% but this did not decrease the number of violations of local standards. Until 1972, Tacoma had the ability to operate both the reverbs simultaneously and we understand that such operations were normal during the winter months. In 1972, Tacoma decided to reroute reverb gases to increase the degree of particulate control by using existing electrostatic precipitators. While the need for SCS at Tacoma may have had a bearing on this decision, the fact remains that since 1972, Tacoma has not had the ability to use both reverbs simultaneously without additional capital investment.

Table IV-2 shows anode production at Tacoma and scrap plus precipitate receipts. The difference between these numbers is a measure of the copper produced from sulfur-bearing materials. The table also shows "tons of material not smelted" as estimated by Asarco. As we understand it, this figure is calculated on the basis of any decrease below a planned smelting rate during a SCS episode, when production is curtailed to meet NAAQS. It appears that this accounting system only measures deviations from a plan during SCS episodes and does not indicate whether the plant can make up for this loss or not. (As discussed below, there is empirical evidence to suggest that some of this "loss" can be made up during good weather.)

Table IV-2 suggests the following:

- In changing from a two-reverb operation to a single-reverb operation in 1972, there might have been a decrease in capacity.

- In 1973, with 17% permanent control, one reverb in operation, and an effective SCS system, Asarco was able to produce at close to the nominal capacity of the smelter. This high production was achieved in spite of the fact that the recorded curtailment was the highest in 1973.

- In 1974 and 1975, with about 48% permanent control (as a result of the liquid SO_2 plant), the production has been less. This suggests that increasing sulfur recovery from 17% to 48% has not significantly improved the productive capcity of the smelter. The decreased production in 1974 and 1975 might have been a result

TABLE IV-2

ANODE PRODUCTION AND SCRAP USAGE AT THE TACOMA SMELTER

Year	Anode and Blister Production (tons)	Precipitates, Low Grade and No. 2 Scrap Receipts (tons)	Difference: Copper from Sulfur-Bearing Materials	Tons of Charge[a] Not Smelted Because of SCS Curtailment	% SO_2 Removed via Permanent Control
1975	72,300	5,400	66,900	54,000	51
1974[b]	86,600	17,700	68,900	78,000	51
1973	95,500	15,800	79,700	85,000	17
1972	99,800	13,400	86,400	-	17
1971[c]	88,200	7,400	80,800	-	17

Notes:
a. As measured by Asarco.
b. Five-week strike
c. Eight-week strike.

Source: Asarco, Inc. data--rounded off by Arthur D. Little, Inc.

of the recession and the slowdown in the copper market starting in 1974. (There was a five week strike in 1974). The operating problems at the liquid SO_2 plant might have also had some effect.

- The table indicates that SCS has not had any effect on copper production in periods of high demand and that there is perhaps sufficient flexibility in the system to make up for lost time so that overall, there is no discernible effect on copper production.

Two questions regarding Tacoma's productive capacity are relevant to this study: what is Tacoma's production capacity under the baseline (no incremental pollution control)? What will be Tacoma's productive capacity if the additional SO_2 controls are installed which would increase sulfur recovery to about 70% or over 90%?

Based on the data in Table IV-2, we estimate Tacoma's productive capacity to be about 78,000 tons/year (of contained copper) for sulfur-bearing materials. Additional production would have to come from sulfur-free materials such as scrap and precipitates. Just as an increase in permanent sulfur control from 17% to 48-51% has had no impact on productive capacity, we believe that an increase in sulfur control to 70% will not significantly alter the capacity.

If an electric smelter is built at Tacoma, this would be "Best Available Control Technology." According to the Tall Stack Guidelines (41FR7450) such a smelter can use unlimited stack height but not SCS.

The PEDCo report did not estimate costs for alternative taller stacks and thus the cost data are consistent only with the use of the existing stack for dispersion of SO_2 emissions. Cramer considered a new stack of about the same height but in a different location.

The Cramer report states that with the present source configuration, the maximum stack emissions should be about 2,500 lb SO_2 per hour in order to meet PSAPCA five-minute and one-hour standards. The emission rate for PEDCo's "maximum control" option, Section 3.5.4; electric furnace smelting (using existing stack) is estimated by PEDCo to be about twice the Cramer figure. This suggests that the electric smelter using the current stack would have to have a smaller capacity in order to comply with the Tall Stack Guidelines. Any increase in capacity would require a taller stack whose height would have to be estimated by diffusion modeling.

The impact analysis assumes that the smelter capacity will not decrease if the reverb is replaced with an electric furnace. While this assumption is consistent with PEDCo's cost data, it is somewhat optimistic in the context of the discussion above and to the extent that the capacity of the electric furnace smelter could be less than 100,000 tons/year, it results in an understatement of economic impact results.

2. Future Raw Material Supply

Tacoma's mix of raw materials has remained quite constant for many years and may be expected to continue in the future--all else equal--except for the situations mentioned below.

Impure concentrates would continue to come from Lepanto and Northern Peru as they have in the past. These concentrates are unacceptable to other smelters, except perhaps in very small quantities, for metallurgical reasons because of the contained impurities. The construction of the Philippine smelter will provide Lepanto or both with another outlet for these concentrates after 1980. Depending on the circumstances they could increase mine production to ship concentrates to both smelters. Otherwise Lepanto or possibly both suppliers would be lost.

Lead smelter byproducts would continue to come from East Helena--all else equal. The size of this stream would shrink after the El Paso antimony plant is in operation. In addition, Asarco has several other potential options for handling this stream as discussed in Chapter III, Section E.

Clean concentrates for Tacoma are likely to come from Duval-Battle Mountain and from mines in Southern Arizona, including other Duval mines. The shipment of these concentrates would continue--all else equal. In the short run, these mines can ship their concentrates to other smelters, i.e., smelters in Japan. In the long-run, other alternatives are available. These are: ship to Japan, ship to a new Arizona smelter, build hydrometallurgical treatment plants, etc. Duval alone produces sufficient concentrates to support a smelter. They also have a hydrometallurgical plant rated at 40,000 tons/year copper.

Another potential source of low impurity concentrates is British Columbia. In the past, Tacoma has not been able to compete for copper concentrates from British Columbia against the Japanese smelters, including concentrates from Granduc. (Granduc is a 50/50 joint venture between Asarco and Newmont and is operated by Newmont. For accounting purposes, Asarco consolidates its interest in Granduc.) (See also Appendix I.) This suggests that the Japanese offer more favorable terms than Tacoma. The provincial government in British Columbia is interested in the industry being integrated forward into smelting and has reportedly subsidized[1] the construction of a small smelter of 25,000 tons/year based on the Top-Blown-Rotary-Converter. This smelter is being built by Afton Mines Ltd. to treat a concentrate high in native copper. The other mines in British Columbia

---

[1] Engineering & Mining Journal, December, 1975, pp. 40-45.

have done studies which suggest that it is cheaper to ship concentrates to Japan.[1] Thus, chances are that Asarco could, at best, procure limited quantities of concentrates from British Columbia for a limited period of time. Furthermore, chances are that such concentrates would be purchased on a "spot" basis, i.e., a one-time purchase of concentrates reflecting short-term excess supply rather than under long-term contracts for continuing supply of concentrates for several years.

Table IV-3 shows the quantities of sulfur-bearing materials that Tacoma might smelt in 1978 and beyond. The quantity of each concentrate is usually consistent with historical operating data over 1973-1976, and has been adjusted when future plans were known. For example, the intake of Lepanto and Northern Peru has been adjusted downwards to be consistent with the reduced production rates. The East Helena byproducts stream is expected to shrink after 1977 but was retained at about the historical average since we were unable to estimate the effect of the new antimony plant. We have assumed, however, that the arsenic trioxide output will decrease by 10% as a result of this change. Tacoma smelts considerable amounts of Southwest concentrates from Duval's mines and other mines such as Twin Buttes. Other miscellaneous shipments would include spot purchases and concentrates acquired under exchange agreements such as Similkameen.

Tacoma also smelts non-sulfur bearing materials such as scrap and precipitates. The smelting rate of these materials has varied much more than that for sulfur-containing materials and depends on the price/availability of these materials. In the 1971-1976 period, the scrap and precipitate receipts varied from 5,400 tons/year to 17,700 tons/year.

For the impact analysis, we have used the scrap and precipitate smelting rate of 22,000 tons/year. This results in a productive smelter capacity of 100,000 tons/year. For the sensitivity analysis, we have also used an alternate basis of 17,000 tons/year of scrap and a total production rate of 95,000 tons/year.

E. PRODUCTION COSTS AND REVENUES AT ASARCO-TACOMA

Table IV-4 shows estimated 1978 costs and income for Asarco-Tacoma. Income from the smelting and refining margin and from byproduct sales is based on recent performance adjusted to a 1978 basis. Because of the structure of the smelting and refining contracts (see Appendix A), the smelting and refining margin at any custom or toll

---

[1] Metals Week, November 1, 1976.

TABLE IV-3

EXPECTED AVERAGE INPUT OF SULFUR-BEARING MATERIALS INTO THE TACOMA SMELTER

	Concentrates		Contained Copper	
	tons/year	%	tons/year	%
1. High Impurity Concentrates				
- Lepanto	60,000	22	19,200	25
- Northern Peru	18,000	7	5,760	7
- East Helena	12,000	4	6,600	8
2. Low Impurity Concentrates				
- Duval Battle Mountain	36,000	13	9,000	11.5
- Other Southwestern concentrates	114,000	41	28,500	37
- Other miscellaneous shipments	36,000	13	9,000	11.5
	276,000	100	78,060	100

Source: Arthur D. Little, Inc. estimates, based on information from Asarco, Inc.

TABLE IV-4

1978 COSTS FOR TACOMA

	100,000 Tons/year[a]		95,000 Tons/year[b]	
	$ MM	¢/lb	$ MM	¢/lb
Income				
Gross margin from smelting and refining	45.4	22.7	43.1	22.7
Byproduct sales	3.6	1.8	3.6	1.9
Total	49.0	24.5	46.7	24.6
Variable Costs				
Fuel and power	10.4		9.9	
Miscellaneous materials and supplies	9.6		9.1	
Direct operating labor	17.0		17.0	
Plant indirects	4.0		4.0	
Subtotal	41.0	20.5	40.0	20.0
Fixed Costs				
G&A Tacoma	1.0		1.0	
G&A (New York allocation)	2.5		2.4	
Depreciation	1.2		1.2	
Pretax profit	3.3		2.1	
Subtotal	8.0	4.0	6.7	3.6
Total	49.0	24.5	46.7	24.6

Notes: a. Based on 100,000 short tons a year; 78,000 tons from sulfur-bearing materials; 22,000 tons from scrap and precipitates.

b. Based on 95,000 short tons a year; 78,000 tons from sulfur-bearing materials; 17,000 tons from scrap and precipitates. These costs are used for a sensitivity analysis.

smelter is essentially independent of the level of copper prices. The operating costs were estimated by breaking down current operating costs into its major components and estimating how they would change in 1978. Asarco's pretax profit at Tacoma over the past 10 years has been about $1.9 million.[1] Based in part on the higher byproduct credits we estimate this to be about $3.3 million in 1978.

The table also shows our estimates of revenues and costs if the smelting and refining rate is 95,000 tons/year. These numbers are used for a sensitivity analysis.

The projected 1978 baseline depreciation-cashflow structure we developed for Tacoma would seem to result in conservative estimates when compared to the earnings actually reported for the period 1965-1974. These latter figures were referred to as Exhibit M in material from Asarco's December 5, 1975 Application for Variance from Regulation 1, Puget Sound Air Pollution Control Agency, and sent to us by EPA Region X.

That is, our pre-tax baseline earnings estimate for Tacoma is $3.3 million/year in 1978 dollars. In comparison, the 1965-1974 average pre-tax earnings reported was $1.85 million, in current dollars. (If we adjust the latter for inflation and express it in equivalent 1978 dollars, it would be roughly $2.8 million).

A discussion of the sensitivity of results to variations in the depreciation and cashflow assumptions is presented in Chapter V, Section G.

---

1 Simon D. Strauss, op. cit., p. 473.

V. ECONOMIC IMPACT ANALYSIS

A. INTRODUCTION

In this chapter, we present an analysis of the economic impact of the various pollution control options being considered at the Tacoma smelter/refinery, to determine on rational financial/economic grounds whether the management of Asarco-Tacoma would be expected to invest in additional control and continue production at Tacoma or decide to discontinue operations, given, clearly, that the Tacoma smelter/refinery will not be able to continue operations into the distant future in its present state, in view of the PSAPCA (Puget Sound Air Pollution Control Agency) SO_2 emission regulations as well as other, basically in-plant, environmental regulations.

This chapter is hence structured to address the complex set of decision-variables, present as well as future conditions and uncertainties, methodological issues and approaches that are required, and the set of theoretically plausible circumstances under which the various control options and other alternatives would be scrutinized by the management.

We start, in Section B, with a brief description of the relationship between the Cramer, PEDCo and Arthur D. Little reports, in order to identify at the outset the extent to which this report uses certain data generated in these two earlier reports and the manner in which such data are used.

Next, Section C presents estimates of incremental compliance costs and their time-phasing under various control options.

The following four sections are exclusively devoted to impact analysis, starting with Section D which describes the methodological framework used in our analysis. Section E then presents a cash flow analysis of incremental pollution control options under base conditions. This is followed, in Section F, by a financial and economic discussion of Tacoma's shutdown. The analysis performed and conclusions reached under base conditions are next extended by conducting a sensitivity analysis in Section G; we examine here the extent to which the conclusions reached earlier need to be modified, by considering a wide range of conditions, including the adoption by Tacoma of a discriminatory monopolistic pricing strategy in the future.

Section H discusses other issues relevant to decision-making at Tacoma.

Finally, Section I contains a discussion of the limitations to the analysis presented in this chapter.

B. RELATIONSHIP BETWEEN CRAMER, PEDCo AND ARTHUR D. LITTLE REPORTS

1. The Cramer Report[1]

The Cramer study used diffusion modeling to determine the degree of constant emission control[2] necessary to meet NAAQS and PSAPCA standards. (These standards are shown in Table V-1.) The study also assessed the reliability of the Asarco SCS system for maintaining both types of air quality standards.

Cramer's findings are as follows:

a. Constant Emission Control

Of the alternatives studied, the six control alternatives shown in Table V-2 provide sufficient degree of permanent control necessary to meet National Ambient Air Quality Standards. The first four of these alternatives also meet PSAPCA standards. The remaining two show marginal compliance, i.e., infrequent violations are possible. Table V-2 shows that with the present stack or a new stack of about the same height, a total emission rate of 2470-1900 lb SO_2/hr is necessary to meet all the applicable standards. This corresponds to 95-96% constant emissions control based on the current production rate. However, this is about half the emission rate that can be obtained through the installation of PEDCo's "maximum control" options.

b. Supplementary Control System

(1) National Standards

The effectiveness of the Asarco SCS in preventing violations of the National standards is shown in Table V-3 which lists the total number of violations per year observed at the PSAPCA monitor located at N26th and Pearl Streets. This monitor has been in operation continuously since 1968 and is the monitor most frequently affected by Asarco emissions. Table V-3

---

[1]H. E. Cramer Co., Inc. (July 1976) "Assessment of the Air Quality Impact of SO_2 Emissions from the Asarco-Tacoma Smelter", EPA 910/9-76-028.

[2]The Stack Height Increase Guidelines (41FR7450) require the use of constant emission limitations as the primary means for achieving ambient air quality standards. When installation of constant controls onto an existing source may be extremely onerous for economic reasons or ill-advised for engineering or siting reasons, techniques could be employed as interim measures provided reasonably available control technology is first installed. Under these conditions, the source in question would be required to conduct a research program to develop new and more economical forms of BACT-caliber technology. The above interpretation of these guidelines is by Arthur D. Little and should not be construed as EPA policy.

TABLE V-1

SO_2 AIR QUALITY STANDARDS APPLICABLE TO THE ASARCO SMELTER

Time Period	National Standards (ppm) Primary	National Standards (ppm) Secondary	Washington DOE Standards (ppm)	PSAPCA Standards (ppm)
5 minutes	-	-	-	1.00[d]
1 hour	-	-	0.40[a]	0.40[b]
1 hour	-	-	0.25[c]	0.25[c]
3 hours	-	0.50[a]	-	-
24 hours	0.14[a]	-	0.10[a]	0.10[b]
30 days	-	-	-	0.04[b]
Annual	0.03[b]	-	0.02[b]	0.02[b]

Notes:
a. Not to be exceeded more than once per year.
b. Never to be exceeded.
c. Not to be exceeded more than two times in any seven consecutive days.
d. Not to be exceeded more than once in any eight consecutive hours.

Source: Cramer (July 1976) op. cit.

TABLE V-2

ASARCO CONTROL ALTERNATIVES WHICH WILL MEET NAAQS

Control Alternative	Total SO_2 Emission Rate (lb/hr)	Percent Constant Emissions Control	Description
7	1,900	96	Electric arc furnace with acid plant on roasters and part of converter stream after enrichment by SO_2 injection, liquid SO_2 plant on remainder of converter stream, existing main stack and modifications outlined in Asarco variance applications.
8	1,900	96	Same as Control Alternative 7 with a new main stack.
9	2,240	96	Existing configuration with scrubber on roaster and reverb streams, existing main stack and modifications outlined in Asarco variance application.
10	2,240	96	Same as Control Alternative 9 with a new main stack.
20	2,470	95	Existing emissions controls on converter stream, roaster and reverb stream to new acid plant following enrichment by SO_2 injection, existing main stack.
21	2,230	96	Existing emissions controls on converter stream, electric arc furnace stream combined with roaster stream to a new acid plant following enrichment by SO_2 injection, existing main stack.

Source: Cramer (July 1976) op. cit.

TABLE V-3

TOTAL NUMBER OF VIOLATIONS OF THE NATIONAL AIR QUALITY STANDARDS FOR SO_2 AT N26TH AND PEARL

Year	Number of Violations*	
	3-Hour Secondary Standard	24-Hour Primary Standard
1976**	3 (4)	3 (4)
1975	0 (0)	0 (0)
1974	0 (1)	0 (0)
1973	0 (0)	0 (0)
1972	0 (0)	0 (0)
1971	1 (2)	1 (2)
1970	5 (6)	1 (2)
1969	5 (6)	4 (5)
1968	0 (1)	1 (2)

*Total number of observations above the standard are enclosed by parentheses.

**1976 data provided by EPA.

Source: Cramer (July 1976) op. cit.

shows that no violations of the National standards were observed at the monitor after 1971 (the SCS was started in 1970) until 1976. In 1976, the 3-hour standard was exceeded four times and the 24-hour standard was exceeded three times with one observation equal to standard. According to Cramer, the success of the Asarco SCS in preventing almost all violations of the National short-term standards is in part due to the curtailment actions and stack-heater operations undertaken in attempting to meet the more stringent PSAPCA short-term standards.

(2) PSAPCA Standards

Table V-4 shows the number of violations of the PSAPCA standards as recorded by the same monitor. It shows that the number of violations of the PSAPCA short-term standards decreased from 1970 through 1973. Since 1973, however, no appreciable decrease in the number of violations has occurred in spite of the addition in 1974 of a liquid SO_2 plant which increased the constant emissions control from 17-48%. Cramer, et al, conclude that the Asarco SCS reached a limit of effectiveness during 1973 and 1974. They also conclude that it is extremely unlikely (emphasis added) that any further significant reductions in the number of violations of the PSAPCA five-minute and one-hour standards can be achieved by SCS techniques with the present source configuration and 51% constant emissions control.

According to Cramer, there is an inherent minimum time delay, which varies from about 20 minutes to one hour or longer, between the time a curtailment decision is made and the time the decision is implemented and the reduction in emissions can affect ambient air quality at SO_2 monitors in the Tacoma area. It follows that it is generally not possible for the Asarco SCS to prevent violations of the PSAPCA five-minute and one-hour standards on the basis of telemetered air quality observations from the Asarco and PSAPCA monitoring networks. Instead, occurrences of high five-minute and one-hour concentrations at monitor locations must be anticipated and curtailment decisions must be made by the Asarco SCS at least 20 minutes to one hour in advance of such occurrences. Although the Asarco meteorologists have become highly skilled in anticipating the occurrence of high SO_2 concentrations, many violations of the PSAPCA five-minute and hourly standards continue to occur. The time-delay constraint in the operation of the Asarco SCS is generally not limiting in the case of the 3-hour and 24-hour National standards and thus telemetered air quality monitor observations can normally be used effectively as a basis for curtailments required to meet these standards.

(3) Fugitives

Cramer, et al, suggest that an increase in the density of the existing SO_2 monitoring network to detect low-level fugitives would result in a significant increase in the number of violations of the PSAPCA five-minute and one-hour air quality standards and appropriate revisions in SCS operating procedures.

TABLE V-4

TOTAL NUMBER OF VIOLATIONS OF THE PSAPCA AIR QUALITY STANDARDS FOR SO_2 AT N26TH AND PEARL

	Number of Violations			
Year	5-Minute Standard of 1.0 ppm	1-Hour Standard of 0.10 ppm*	1-Hour Standard of 0.25 ppm	24-Hour Standard of 0.10 ppm*
1976**	20	18	20	5
1975	8	6	35	0
1974	10	6	21	1
1973	16	4	27	0
1972	27	11	34	0
1971	39	20	52	3
1970	169	62	140	4
1969	199	84	219	15
1968	124	56	125	10

*This appears to be a typographical error in the Cramer report. The one hour standard is 0.40 ppm.

**1976 data provided by EPA; violations are only shown in instances when standard was exceeded by 10% or more.

Source: Cramer (July 1976) op. cit.

2. The PEDCo Report[1]

The PEDCo report considered various alternatives for increasing the degree of constant control for reducing SO_2 emissions. The control options in this report fall into three categories which can be labelled as "minimum", "intermediate", and "maximum" controls using either cost or the incremental SO_2 recovered as criteria.

3. Arthur D. Little Report

As explained in the next section, we selected (based on discussions with the EPA), three specific options to represent the "minimum", "intermediate", and "maximum" control categories.

None of the alternatives considered by PEDCo have emissions sufficiently low to meet the requirements for constant emission control. As noted earlier, the emissions from the "maximum" control electric furnace alternative are about twice the level necessary to meet the requirements of constant emission control. As noted in Chapter IV, Section C, we have assumed that if an electric furnace smelter is built in Tacoma, it would have the same capacity as the current plant and not have a smaller capacity. To the extent that the capacity of the electric smelter would be less because of the requirements of the Stack Height Increase Guidelines, the economic impact results are understated.

C. COMPLIANCE COSTS AT ASARCO-TACOMA UNDER ALTERNATIVE CONTROL OPTIONS

1. Control Costs

Based on discussions with the EPA, the following costs were selected as representative of three cost categories:

- "Minimum" control: Costs for the Browder improvements (PEDCo Section 3.3.2).
- "Intermediate" control: Costs from the PEDCo report (Section 3.4.2)--"Roaster Gas Enrichment with SO_2 Injection and Acid Plant Consolidation (at 100% gas flow)."
- "Maximum" control: Costs from the PEDCo report (Section 3.5.4) for electric furnace smelting.

In addition, there are other incremental costs which will be incurred in the future but which are not related to incremental SO_2 control. These are:

- Particulate control costs: These relate to improvements in the particulate control system agreed to by Asarco as a part of the variance granted in 1976.

[1] PEDCo-Environmental (September 1976) "Evaluation of Sulfur Dioxide and Arsenic Control Techniques for the Asarco-Tacoma Smelter", EPA 68-02-1321 - Task Order No. 35.

- OSHA costs for inorganic arsenic: These relate to the costs for meeting the proposed OSHA standard of 0.004 mg As/m^3 for inorganic arsenic.

The capital investment (in 1978 dollars) and operating and maintenance costs or variable costs (i.e., direct operating costs exclusive of fixed charges) for all approaches are shown in Table V-5. Appendix M discusses, in detail, the procedures used to convert the annualized costs into O&M costs.

2. Definitions of Alternative Control Options

For purposes of economic impact analysis, four alternative control options at Asarco-Tacoma have been defined as follows, with and without (i.e., including and not including) compliance with OSHA-related arsenic emission regulations:

- OPTION 1: Electric furnace smelting; acid plant consolidation; particulate control[1]

- OPTION 2: Roaster gas enrichment; acid plant consolidation; particulate control[1]

- OPTION 3: Improve existing acid plant; roaster gas enrichment; subsequent acid plant consolidation; particulate control[1]

- OPTION 4: Improve existing acid plant; particulate control[1]

These four alternative control operations, without and with OSHA-related regulations, are designated here as follows:

- Option 1.1 - Option 1, without OSHA
  Option 1.2 - Option 1, with OSHA

- Option 2.1 - Option 2, without OSHA
  Option 2.2 - Option 2, with OSHA

- Option 3.1 - Option 3, without OSHA
  Option 3.2 - Option 3, with OSHA

- Option 4.1 - Option 4, without OSHA
  Option 4.2 - Option 4, with OSHA

All options include particulate control (i.e., baghouses), as a prerequisite; the without-OSHA, with-OSHA designations are used for analytical purposes

[1] This refers to particulate control measures to be provided by Asarco as a part of the 1976 variance.

TABLE V-5

INCREMENTAL COSTS AT ASARCO-TACOMA FOR VARIOUS OPTIONS
(1978$)

	Approach	Capital Investment (millions)	Operating and Maintenance Costs (millions)
Incremental SO_2 Control			
Minimum Control	Improve Existing Acid Plant	1.5	0.2
Intermediate Control	Roaster Gas Enrichment - Acid Plant Consolidation	34.9	5.5
Maximum Control	Electric Furnace Smelting - Acid Plant Consolidation	55.9	5.8
Baseline Costs			
Particulate Control	Asarco Variance Application	5.6	0.8
OSHA	0.004 mg As/m^3 Arthur Young Costs	36.0	4.8

only, to keep account of economic impacts due to not only alternative options to reduce SO_2 emissions but also to comply with OSHA's proposed standard for inorganic arsenic.[1]

3. Estimates of Incremental Pollution Abatement Expenditures under Alternative Control Options

Estimates of incremental pollution abatement expenditures at Asarco-Tacoma under alternative control options, with and without OSHA, are tabulated in Table V-6, based on the PEDCo and Arthur Young & Company estimates, expressed in 1978 dollars. It should be noted that there is little synergism between OSHA and EPA costs and these costs are additive. These incremental expenditures (both total capital investment and annual operating and maintenance costs) are normalized around an average annual smelting/refining which is about the same as the historical average. Thus, this is consistent with the assumption that the productive capacity of Asarco-Tacoma will remain constant during the impact analysis period.

4. Time-Phasing of Incremental Pollution Abatement Expenditures at Asarco-Tacoma under Alternative Control Options

Tables V-7 through V-10 show the time-phasing of incremental pollution abatement expenditures at Asarco-Tacoma, over the 1978-1995 period, under the four alternative control options, with and without OSHA. In this connection, the following assumed timetables for incremental capital investment should be noted:

- Electric furnace smelting: 1980-1983;
- Particulate control: 1978-1979;
- Roaster gas enrichment; acid plant consolidation: 1978-1981 (Option 2) and 1981-1984 (Option 3);
- Improvement of existing acid plant: 1978-1979; and
- OSHA-related capital investment: 1978-1983.

---

[1] U. S. Department of Labor, Occupational Safety and Health Administration (OSHA) proposed that average exposure levels during an eight-hour period should not exceed 0.004 mg As/m^3. In arriving at this standard, OSHA considered other alternatives (i.e., 0.1 mg As/m^3 and 0.005 mg As/m^3, where the latter is the existing permissible level). For a detailed review, refer to OSHA's inflationary impact statement on arsenic, entitled, "Technological Feasibility Analysis and Inflationary Impact Statement for the Proposed Standard for Inorganic Arsenic (40FR3392)", Final Report, 1976 (prepared by Arthur Young & Company). Also refer to the record of OSHA's arsenic hearing in September-October 1976.

TABLE V-6

INCREMENTAL COSTS AT ASARCO-TACOMA UNDER ALTERNATIVE CONTROL OPTIONS
(millions of 1978 dollars)

	WITHOUT OSHA		WITH OSHA	
Control Options	Capital Investment (Total)	Operating and Maintenance Costs (per year)	Capital Investment (Total)	Operating and Maintenance Costs (per year)
			36.0	4.8
OPTION 1				
Electric furnace smelting; acid plant consolidation	55.9	5.8	-	-
Particulate control	5.6	0.8	-	-
TOTAL	61.5	6.6	97.5	11.4
OPTION 2				
Roaster gas enrichment; acid plant consolidation	34.9	5.5	-	-
Particulate control	5.6	0.8	-	-
TOTAL	40.5	6.3	76.5	11.1
OPTION 3				
Improve existing acid plant	1.5	0.2	-	-
Roaster gas enrichment; acid plant consolidation	34.9	5.5	-	-
Particulate control	5.6	0.8	-	-
TOTAL	42.0	6.5	78.0	11.3
OPTION 4				
Improve existing acid plant	1.5	0.2	-	-
Particulate control	5.6	0.8	-	-
TOTAL	7.1	1.0	43.1	5.8

Source: Based on Table V-5.

TABLE V-7

TIME-PHASING OF INCREMENTAL POLLUTION ABATEMENT EXPENDITURES AT ASARCO-TACOMA UNDER CONTROL OPTION 1
(millions of 1978 dollars)

Description	1978	1979	1980	1981	1982	1983	1984	1985	...	1995
OPTION 1, WITHOUT OSHA (1.1)										
Capital Investment										
Electric furnace smelting	-	-	13.98	13.98	13.98	13.98	-	-	...	-
Particulate control	2.80	2.80	-	-	-	-	-	-	...	-
TOTAL	2.80	2.80	13.98	13.98	13.98	13.98	-	-	...	-
Operating and Maintenance Costs										
Electric furnace smelting	-	-	-	-	-	-	5.80	5.80	...	5.80
Particulate control	-	-	0.80	0.80	0.80	0.80	0.80	0.80	...	0.80
TOTAL	-	-	0.80	0.80	0.80	0.80	6.60	6.60	...	6.60
OPTION 1, WITH OSHA (1.2)										
Capital Investment										
Subtotal Without OSHA (See above)	2.80	2.80	13.98	13.98	13.98	13.98	-	-	...	-
OSHA	6.00	6.00	6.00	6.00	6.00	6.00	-	-	...	-
TOTAL	8.80	8.80	19.98	19.98	19.98	19.98	-	-	...	-
Operating and Maintenance Costs										
Subtotal Without OSHA (See above)	-	-	0.80	0.80	0.80	0.80	6.60	6.60	...	6.60
OSHA	-	-	0.60	1.20	2.40	3.60	4.80	4.80	...	4.80
TOTAL	-	-	1.40	2.00	3.20	4.40	11.40	11.40	...	11.40

Source: Refer to Table V-6 for the total amounts used before time-phasing them; assumptions underlying the time-phasing of the various types of incremental pollution abatement expenditures are explained in the accompanying text.

TABLE V-8

TIME-PHASING OF INCREMENTAL POLLUTION ABATEMENT EXPENDITURES
AT ASARCO-TACOMA UNDER CONTROL OPTION 2
(millions of 1978 dollars)

Description	1978	1979	1980	1981	1982	1983	1984	1985	...	1995
OPTION 2, WITHOUT OSHA (2.1)										
Capital Investment										
Roaster gas enrichment; acid plant consolidation	8.73	8.73	8.73	8.73	-	-	-	-	...	-
Particulate control	2.80	2.80	-	-	-	-	-	-	...	-
TOTAL	11.53	11.53	8.73	8.73	-	-	-	-	...	-
Operating and Maintenance Costs										
Roaster gas enrichment; acid plant consolidation	-	-	-	-	5.50	5.50	5.50	5.50	...	5.50
Particulate control	-	-	0.80	0.80	0.80	0.80	0.80	0.80	...	0.80
TOTAL	-	-	0.80	0.80	6.30	6.30	6.30	6.30	...	6.30
OPTION 2, WITH OSHA (2.2)										
Capital Investment										
Subtotal Without OSHA (See above)	11.53	11.53	8.73	8.73	-	-	-	-	...	-
OSHA	6.00	6.00	6.00	6.00	6.00	6.00	-	-	...	-
TOTAL	17.53	17.53	14.73	14.73	6.00	6.00	-	-	...	-
Operating and Maintenance Costs										
Subtotal Without OSHA (See above)	-	-	0.80	0.80	6.30	6.30	6.30	6.30	...	6.30
OSHA	-	-	0.60	1.20	2.40	3.60	4.80	4.80	...	4.80
TOTAL	-	-	1.40	2.00	8.70	9.90	11.10	11.10	...	11.10

Source: Refer to Table V-6 for the total amounts used before time-phasing them; assumptions underlying the time-phasing of the various types of incremental pollution abatement expenditures are explained in the accompanying text.

TABLE V-9

TIME-PHASING OF INCREMENTAL POLLUTION ABATEMENT EXPENDITURES
AT ASARCO-TACOMA UNDER CONTROL OPTION 3
(millions of 1978 dollars)

Description	1978	1979	1980	1981	1982	1983	1934	1985	...	1995
OPTION 3, WITHOUT OSHA (3.1)										
Capital Expenditures										
Improve existing acid plant	0.75	0.75	-	-	-	-	-	-	...	-
Roaster gas enrichment; acid plant consolidation	-	-	-	8.73	8.73	8.73	8.73	-	...	-
Particulate control	2.80	2.80	-	-	-	-	-	-	...	-
TOTAL	3.55	3.55	-	8.73	8.73	8.73	8.73	-	...	-
Operating Maintenance Costs										
Improve existing acid plant	-	-	0.20	0.20	0.20	0.20	0.20	0.20	...	0.20
Roaster gas enrichment; acid plant consolidation	-	-	-	-	-	-	-	5.50	...	5.50
Particulate control	-	-	0.80	0.80	0.80	0.80	0.80	0.80	...	0.80
TOTAL	-	-	1.00	1.00	1.00	1.00	1.00	6.50	...	6.50
OPTION 3, WITH OSHA (3.2)										
Capital Investment										
Subtotal Without OSHA (See above)	3.55	3.55	-	8.73	8.73	8.73	8.73	-	...	-
OSHA	6.00	6.00	6.00	6.00	6.00	6.00	-	-	...	-
TOTAL	9.55	9.55	6.00	14.73	14.73	14.73	8.73	-	...	-
Operating and Maintenance Costs										
Subtotal Without OSHA (See above)	-	-	1.00	1.00	1.00	1.00	1.00	6.50	...	6.50
OSHA	-	-	0.60	1.20	2.40	3.60	4.80	4.80	...	4.80
TOTAL	-	-	1.60	2.20	3.40	4.60	5.80	11.30	...	11.30

Source: Refer to Table V-6 for the total amounts used before time-phasing them; assumptions underlying the time-phasing of the various types of incremental pollution abatement expenditures are explained in the accompanying text.

TABLE V-10

TIME-PHASING OF INCREMENTAL POLLUTION ABATEMENT EXPENDITURES AT ASARCO-TACOMA UNDER CONTROL OPTION 4
(millions of 1978 dollars)

Description	1978	1979	1980	1981	1982	1983	1984	1985	...	1995
OPTION 4, WITHOUT OSHA (4.1)										
Capital Investment										
Improve existing acid plant	0.75	0.75	-	-	-	-	-	-	...	-
Particulate control	2.80	2.80	-	-	-	-	-	-	...	-
TOTAL	3.55	3.55	-	-	-	-	-	-	...	-
Operating and Maintenance Costs										
Improve existing plant	-	-	0.20	0.20	0.20	0.20	0.20	0.20	...	0.20
Particulate control	-	-	0.80	0.80	0.80	0.80	0.80	0.80	...	0.80
TOTAL	-	-	1.00	1.00	1.00	1.00	1.00	1.00	...	1.00
OPTION 4, WITH OSHA (4.2)										
Capital Investment										
Subtotal Without OSHA (See above)	3.55	3.55	-	-	-	-	-	-	...	-
OSHA	6.00	6.00	6.00	6.00	6.00	6.00	-	-	...	-
TOTAL	9.55	9.55	6.00	6.00	6.00	6.00	-	-	...	-
Operating and Maintenance Costs										
Subtotal Without OSHA (See above)	-	-	1.00	1.00	1.00	1.00	1.00	1.00	...	1.00
OSHA	-	-	0.60	1.20	2.40	3.60	4.80	4.80	...	4.80
TOTAL	-	-	1.60	2.20	3.40	4.60	5.80	5.80	...	5.80

Source: Refer to Table V-6 for the total amounts used before time-phasing them; assumptions underlying the time-phasing of the various types of incremental pollution abatement expenditures are explained in the accompanying text.

Incremental capital investment over these periods is assumed to take place in equal amounts in various years. Operating and maintenance costs are assumed to take effect upon completion of the particular pollution abatement investment program (except in the case of OSHA-related operating and maintenance costs which are assumed to start in 1980 and gradually build up to the expected annual average level by 1984).

It can be seen from Tables V-8 and V-9 that the main difference between Options 2 and 3 involves the time-phasing of capital investment for roaster gas enrichment and acid plant consolidation (1978-1981 under Option 2 and 1981-1984 under Option 3).

All major reconstruction projects require that the work proceed at a particular pace or cadence. While the estimated impact would be less if these expenditures were spread over a much longer period of time, the estimated compliance costs would not necessarily remain constant under these conditions. They would increase because of inefficiencies and interference within the operating plant.

5. Variability in Estimates of Incremental Pollution Abatement Expenditures and Selection of Control Options/Compliance Cost Estimates for Economic Impact Analysis

The incremental pollution abatement expenditures and their timetables given in Tables V-6 through V-10 represent "base case" estimates which may vary within a range of -5 and +25%. This range is representative of the variability in cost estimating procedures normally used for preparing such estimates.

Table V-11 shows the levels, ranges, and time-phasing of incremental pollution abatement expenditures at Asarco-Tacoma under the four alternative control options, with and without OSHA. The -5% and +25% range around the "base" estimates are assumed only for incremental pollution abatement capital expenditures; the estimated operating and maintenance costs under a given control option are assumed to be the same for the compliance cost ranges A (25% above base), B (base), and C (5% below base).

OSHA-related capital expenditures, although not reflecting PEDCo estimates[1], are also assumed to be subject to the same range of variability. This assumption reduces the number of analytical options to a manageable level.

An inspection of Table V-11 reveals 24 distinct analytical options: four alternative control options, each with two sub-options (without OSHA, with OSHA), where each sub-option, in turn, has three variants A, B, and C. Clearly, conducting an economic impact analysis of each one of these 24 analytical options, each defining a control option/compliance cost

---

[1] They are based on Arthur Young & Company estimates.

TABLE V-11

LEVELS, RANGES, AND TIME-PHASING OF INCREMENTAL POLLUTION ABATEMENT EXPENDITURES AT ASARCO-TACOMA UNDER ALTERNATIVE CONTROL OPTIONS, WITH AND WITHOUT OSHA
(millions of 1978 dollars)

Description	Total	1978	1979	1980	1981	1982	1983	1984	1985	...	1995
OPTION 1, WITHOUT OSHA (1.1)											
Capital Investment											
Option 1.1A: 25% Above Base	76.9	3.50	3.50	17.47	17.47	17.47	17.47	-	-	...	-
Option 1.1B: Base[a]	61.5	2.80	2.80	13.98	13.98	13.98	13.98	-	-	...	-
Option 1.1C: 5% Below Base	58.4	2.66	2.66	13.23	13.28	13.28	13.28	-	-	...	-
Operating and Maintenance Costs[b]	-	-	-	0.80	0.80	0.80	0.80	6.60	6.60	...	6.60
OPTION 1, WITH OSHA (1.2)											
Capital Investment											
Option 1.2A: 25% Above Base	121.9	11.00	11.00	24.98	24.98	24.98	24.98	-	-	...	-
Option 1.2B: Base[a]	97.5	8.80	8.80	19.98	19.98	19.98	19.98	-	-	...	-
Option 1.2C: 5% Below Base	92.6	8.36	8.36	18.98	18.98	18.98	18.98	-	-	...	-
Operating and Maintenance Costs[b]	-	-	-	1.40	2.00	3.20	4.40	11.40	11.40	...	11.40
OPTION 2, WITHOUT OSHA (2.1)											
Capital Investment											
Option 2.1A: 25% Above Base	50.6	14.41	14.41	10.91	10.91	-	-	-	-	...	-
Option 2.1B: Base[a]	40.5	11.53	11.53	8.73	8.73	-	-	-	-	...	-
Option 2.1C: 5% Below Base	38.5	10.95	10.95	8.29	8.29	-	-	-	-	...	-
Operating and Maintenance Costs[b]	-	-	-	0.80	0.80	6.30	6.30	6.30	6.30	...	6.30
OPTION 2, WITH OSHA (2.2)											
Capital Investment											
Option 2.2A: 25% Above Base	95.6	21.91	21.91	18.41	18.41	7.50	7.50	-	-	...	-
Option 2.2B: Base[a]	76.5	17.53	17.53	14.73	14.73	6.00	6.00	-	-	...	-
Option 2.2C: 5% Below Base	72.7	16.65	16.65	13.99	13.99	5.70	5.70	-	-	...	-
Operating and Maintenance Costs[b]	-	-	-	1.40	2.00	8.70	9.90	11.10	11.10	...	11.10
OPTION 3, WITHOUT OSHA (3.1)											
Capital Investment											
Option 3.1A: 25% Above Base	52.5	4.44	4.44	-	10.91	10.91	10.91	10.91	-	...	-
Option 3.1B: Base[a]	42.0	3.55	3.55	-	8.73	8.73	8.73	8.73	-	...	-
Option 3.1C: 5% Below Base	39.9	3.37	3.37	-	8.29	8.29	8.29	8.29	-	...	-
Operating and Maintenance Costs[b]	-	-	-	1.00	1.00	1.00	1.00	1.00	6.50	...	6.50
OPTION 3, WITH OSHA (3.2)											
Capital Investment											
Option 3.2A: 25% Above Base	97.5	11.94	11.94	7.50	18.41	18.41	18.41	10.91	-	...	-
Option 3.2B: Base[a]	78.0	9.55	9.55	6.00	14.73	14.73	14.73	8.73	-	...	-
Option 3.2C: 5% Below Base	74.1	9.07	9.07	5.70	13.99	13.99	13.99	8.29	-	...	-
Operating and Maintenance Costs[b]	-	-	-	1.60	2.20	3.40	4.60	5.80	11.30	...	11.30
OPTION 4, WITHOUT OSHA (4.1)											
Capital Investment											
Option 4.1A: 25% Above Base	8.9	4.44	4.44	-	-	-	-	-	-	...	-
Option 4.1B: Base[a]	7.1	3.55	3.55	-	-	-	-	-	-	...	-
Option 4.1C: 5% Below Base	6.7	3.37	3.37	-	-	-	-	-	-	...	-
Operating and Maintenance Costs[b]	-	-	-	1.00	1.00	1.00	1.00	1.00	1.00	...	1.00
OPTION 4, WITH OSHA (4.2)											
Capital Investment											
Option 4.2A: 25% Above Base	53.9	11.94	11.94	7.50	7.50	7.50	7.50	-	-	...	-
Option 4.2B: Base[a]	43.1	9.55	9.55	6.00	6.00	6.00	6.00	-	-	...	-
Option 4.2C: 5% Below Base	40.9	9.07	9.07	5.70	5.70	5.70	5.70	-	-	...	-
Operating and Maintenance Costs[b]	-	-	-	1.60	2.20	3.40	4.60	5.80	5.80	...	5.80

Notes and Sources:
a. From Tables V-6 through V-10.
b. Assumed to be the same under the compliance cost ranges A, B, C for each control option (with or without OSHA).

combination, would prove a largely repetitious and time-consuming method of assessing the economic impacts of the four alternative control options. A limited, representative number of these 24 analytical options can be selected for impact analysis purposes, in order to address fully and efficiently the spectrum of impacts associated with these 24 analytical options.

The following five options out of the full range of 24, have been selected for impact analysis purposes (Note: required incremental capital investment levels are given in parentheses, expressed in millions of 1978 dollars):

- Option 1.2B (97.5), which represents Option 1 with OSHA (base case), broadly covers the following control option/compliance cost combination:

  1.2A (121.9)
  3.2A (97.5)

- Option 1.1B (61.5), which represents Option 1 without OSHA (base case), broadly covers the following control option/compliance cost combinations:

  1.1A (76.9)
  2.2B (76.5)
  3.2C (74.1)
  2.2C (72.7)

- Option 3.2B (78.0), which represents Option 3 with OSHA (base case), broadly covers the following control option/compliance cost combinations:

  2.2A (95.6)
  1.2C (92.6)

- Option 3.1B (42.0), which represents Option 3 without OSHA (base case), broadly covers the following control option/compliance cost combinations:

  2.1B (40.5)
  4.2C (40.9)
  3.1C (39.9)
  2.1C (38.5)

- Option 4.2B (43.1), which represents Option 4 with OSHA (base case), broadly covers the following control option/compliance cost combinations:

  1.1C (58.4)
  4.2A (53.9)
  3.1A (52.5)
  2.1A (50.6)

Three remaining control option/compliance cost combinations are omitted from consideration, by inspection as analytically "trivial" cases:[1]

- 4.1A (8.9)
- 4.1B (7.1)
- 4.1C (6.7)

The selection of Options 1.2B, 1.1B, 3.1B, 3.2B and 4.2B to bracket the problem analytically for impact analysis purposes reflects the following basic considerations:

- If Asarco-Tacoma cannot successfully undertake the incremental pollution abatement expenditures programs specified under Options 1.2B, 1.1B, 3.1B, 3.2B and 4.2B (in the sense that it would face a shutdown decision now or in the future precipitated by a combination of factors due to these options), then it is highly unlikely that Asarco-Tacoma would survive the control option/compliance cost combinations enumerated above by these respective options.

- Conversely, if Asarco-Tacoma can successfully meet Option 1.2B, 1.1B, 3.2B, 3.1B and 4.2B, then it is highly likely that it can also meet the control option/compliance cost combination covered by these options.

Differences in time-phasing and levels of operating and maintenance costs under the various control option/compliance cost combinations may possibly render the selection of Options 1.2B, 1.1B, 3.2B, 3.1B and 4.2B somewhat less than perfect. Nevertheless, we believe they provide an appropriately representative set of options to use for impact analysis purposes. It may be noted, in this respect, that Options 2 and 3 are virtually interchangeable, and differ mainly in terms of the time-phasing of the incremental capital investment associated with roaster gas enrichment and acid plant consolidation. Under Option 3, incremental capital expenditures are spread over the years 1981-1984, whereas under Option 2 they take place over the period 1978-1981. In other words, for all practical purposes, Option 3 provides a "gradual" version of Option 2, and includes some redundancy such that should Asarco-Tacoma fail to meet Option 3, then it quite likely will fail to meet Option 2. (This implies that Option 2 would warrant additional impact analysis should Asarco-Tacoma appear to meet Option 3.)

---

[1]That is to say, these cases would warrant analysis only if Asarco-Tacoma would clearly fail to meet even the lowest cost of the five options selected for analysis.

6. Translation of Incremental Pollution Abatement Expenditures to Annual O&M Costs and Annualized Compliance Costs for Impact Analysis Purposes

a. General

Tables V-12 through V-16 translate the incremental pollution abatement capital expenditures and operating and maintenance costs under Options 1.2B, 1.1B, 3.2B, 3.1B and 4.2B into annualized compliance costs (i.e., annualized fixed costs, operating and maintenance costs per year, and total annualized compliance costs).

b. Cash Flow Analysis

Capital outlays and year-by-year O&M costs are used for the cash flow analysis. The table includes capital outlays for pollution abatement replacement investment at 3% of total pollution abatement investment in place, taking place after the plant is in operation following the installation of the pollution abatement machinery and equipment under the various control options (i.e., starting in 1984 or 1985, depending on the control option).

The estimate of annual replacement at 3% of original investment, for a new plant and equipment, is based on established engineering practice in such studies and is typical of the copper industry.

c. Annualized Costs

Annualized costs are necessary for the alternative approach for impact analysis discussed in Appendix L.

The capital investment is converted into annualized fixed costs by multiplying the investment by a fixed charge coefficient. A fixed charge coefficient of 17% was used in our analysis. This is about the same as the 17.65% figure used by PEDCo.

D. METHODOLOGY OF IMPACT ANALYSIS

1. Introduction

Under any incremental pollution control scenario, Asarco-Tacoma faces increased costs of production over the foreseeable future. The costs of compliance under these conditions, defined narrowly to include both capital expenditures (fixed costs) and operating and maintenance expenses (variable costs), cause an upward shift in Tacoma's pertinent

TABLE V-12

ANNUALIZED COMPLIANCE COSTS AT ASARCO-TACOMA UNDER OPTION 1.2B
(CONTROL OPTION 1, WITH OSHA, BASE CASE) 1978-1996
(millions of 1978 dollars)

Years when fixed costs are faced	Years when pollution abatement capital expenditures (dollar outflows) takes place[a]																		Annualized Fixed Costs by Year[b]	Operating and Maintenance Costs by Year[a]	Total Annualized Compliance Costs by Year
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995			
	8.80	8.80	19.98	19.98	19.98	19.98	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93			
1978																			-	-	-
1979	1.50																		1.50	-	1.50
1980	1.50	1.50																	3.00	1.40	4.40
1981	1.50	1.50	3.40																6.40	2.00	8.40
1982	1.50	1.50	3.40	3.40															9.80	3.20	13.00
1983	1.50	1.50	3.40	3.40	3.40														13.20	4.40	17.60
1984	1.50	1.50	3.40	3.40	3.40	3.40													16.60	11.40	28.00
1985	1.50	1.50	3.40	3.40	3.40	3.40	.50												17.10	11.40	28.50
1986	1.50	1.50	3.40	3.40	3.40	3.40	.50	.50											17.60	11.40	29.00
1987	1.50	1.50	3.40	3.40	3.40	3.40	.50	.50	.50										18.10	11.40	29.50
1988	1.50	1.50	3.40	3.40	3.40	3.40	.50	.50	.50	.50									18.60	11.40	30.00
1989	1.50	1.50	3.40	3.40	3.40	3.40	.50	.50	.50	.50	.50								19.10	11.40	30.50
1990		1.50	3.40	3.40	3.40	3.40	.50	.50	.50	.50	.50	.50							18.10	11.40	29.50
1991			3.40	3.40	3.40	3.40	.50	.50	.50	.50	.50	.50	.50						17.10	11.40	28.50
1992				3.40	3.40	3.40	.50	.50	.50	.50	.50	.50	.50	.50					14.20	11.40	25.60
1993					3.40	3.40	.50	.50	.50	.50	.50	.50	.50	.50	.50				11.30	11.40	22.70
1994						3.40	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50			8.40	11.40	19.80
1995							.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50		5.50	11.40	16.90
1996								.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	5.50	11.40	16.90

Notes and Sources:
a. From Table V-11.
b. Reflect the following major assumptions: (1) capital recovery period of 11 years; (2) fixed charge coefficient of 0.17 (i.e., 17.0%); (3) capital outlays for pollution abatement replacement investment at 3% of total pollution abatement investment in place, taking place after the plant is in operation following the installation of the pollution abatement machinery and equipment under the various control options (i.e., starting in 1984 or 1985, depending on the control option).

TABLE V-13

ANNUALIZED COMPLIANCE COSTS AT ASARCO-TACOMA UNDER OPTION 1.1B
(CONTROL OPTION 1, WITHOUT OSHA, BASE CASE), 1978-1996
(millions of 1978 dollars)

Years when fixed costs are faced	Years when pollution abatement capital expenditures (dollar outflows) take place[a]																		Annualized Fixed Costs by Year[b]	Operating and Maintenance Costs by Year[a]	Total Annualized Compliance Costs by Year
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995			
	2.80	2.80	13.98	13.98	13.98	13.98	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85			
1978																			-	-	-
1979	.48																		.48	-	.48
1980	.48	.48																	.96	.80	1.76
1981	.48	.48	2.38																3.34	.80	4.14
1982	.48	.48	2.38	2.38															5.72	.80	6.52
1983	.48	.48	2.38	2.38	2.38														8.10	.80	8.90
1984	.48	.48	2.38	2.38	2.38	2.38													10.48	6.60	17.08
1985	.48	.48	2.38	2.38	2.38	2.38	.31												10.79	6.60	17.39
1986	.48	.48	2.38	2.38	2.38	2.38	.31	.31											11.10	6.60	17.70
1987	.48	.48	2.38	2.38	2.38	2.38	.31	.31	.31										11.41	6.60	18.01
1988	.48	.48	2.38	2.38	2.38	2.38	.31	.31	.31	.31									11.72	6.60	18.32
1989	.48	.48	2.38	2.38	2.38	2.38	.31	.31	.31	.31	.31								12.03	6.60	18.63
1990		.48	2.38	2.38	2.38	2.38	.31	.31	.31	.31	.31	.31							11.86	6.60	18.46
1991			2.38	2.38	2.38	2.38	.31	.31	.31	.31	.31	.31	.31						11.69	6.60	18.29
1992				2.38	2.38	2.38	.31	.31	.31	.31	.31	.31	.31	.31					9.62	6.60	16.22
1993					2.38	2.38	.31	.31	.31	.31	.31	.31	.31	.31	.31				7.55	6.60	14.15
1994						2.38	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31			5.48	6.60	12.08
1995							.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31		3.41	6.60	10.01
1996								.31	.31	.31	.31	.31	.3.	.31	.31	.31	.31	.31	3.41	6.60	10.01

Notes and Sources:
a. From Table V-11.
b. Reflect the following major assumptions: (1) capital recovery period of 11 years; (2) fixed charge coefficient of 0.17 (i.e., 17.0%); (3) capital outlays for pollution abatement replacement investment at 3% of total pollution abatement investment in place, taking place after the plant is in operation following the installation of the pollution abatement machinery and equipment under the various control options (i.e., starting in 1984 or 1985, depending on the control option).

TABLE V-14

ANNUALIZED COMPLIANCE COSTS AT ASARCO-TACOMA UNDER OPTION 3.2B (CONTROL OPTION 3, WITH OSHA, BASE CASE), 1978-1996

(millions of 1978 dollars)

Years when fixed costs are faced	Years when pollution abatement capital expenditures (dollar outflows) take place[a]																		Annualized Fixed Costs by Year[b]	Operating and Maintenance Costs by Year[a]	Total Annualized Compliance Costs by Year
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995			
	9.55	9.55	6.00	14.73	14.73	14.73	8.73	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34			
1978																			-	-	-
1979	1.62																		1.62	-	1.62
1980	1.62	1.62																	3.24	1.60	4.84
1981	1.62	1.62	1.02																4.26	2.20	6.46
1982	1.62	1.62	1.02	2.50															6.76	3.40	10.16
1983	1.62	1.62	1.02	2.50	2.50														8.26	4.60	13.86
1984	1.62	1.62	1.02	2.50	2.50	2.50													11.76	5.80	17.56
1985	1.62	1.62	1.02	2.50	2.50	2.50	1.48												13.24	11.30	24.54
1986	1.62	1.62	1.02	2.50	2.50	2.50	1.48	.40											13.64	11.30	24.94
1987	1.62	1.62	1.02	2.50	2.50	2.50	1.48	.40	.40										14.04	11.30	25.34
1988	1.62	1.62	1.02	2.50	2.50	2.50	1.48	.40	.40	.40									14.44	11.30	25.74
1989	1.62	1.62	1.02	2.50	2.50	2.50	1.48	.40	.40	.40	.40								14.84	11.30	26.14
1990		1.62	1.02	2.50	2.50	2.50	1.48	.40	.40	.40	.40	.40							13.62	11.30	24.92
1991			1.02	2.50	2.50	2.50	1.48	.40	.40	.40	.40	.40	.40						12.40	11.30	23.70
1992				2.50	2.50	2.50	1.48	.40	.40	.40	.40	.40	.40	.40					11.78	11.30	23.08
1993					2.50	2.50	1.48	.40	.40	.40	.40	.40	.40	.40	.40				9.68	11.30	20.98
1994						2.50	1.48	.40	.40	.40	.40	.40	.40	.40	.40	.40			7.58	11.30	18.88
1995							1.48	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40		5.48	11.30	16.78
1996								.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	4.40	11.30	15.70

Notes and Sources:

a. From Table V-11.

b. Reflect the following major assumptions: (1) capital recovery period of 11 years; (2) fixed charge coefficient of 0.17 (i.e., 17.0%); (3) capital outlays for pollution abatement replacement investment at 3% of total pollution abatement investment in place, taking place after the plant is in operation following the installation of the pollution abatement machinery and equipment under the various control options (i.e., starting in 1984 or 1985, depending on the control option).

TABLE V-15

ANNUALIZED COMPLIANCE COSTS AT ASARCO-TACOMA UNDER OPTION 3.1B (CONTROL OPTION 3, WITHOUT OSHA, BASE CASE), 1978-1996

(millions of 1978 dollars)

Years when fixed costs are faced	Years when pollution abatement capital expenditures (dollar outflows) take place[a]																		Annualized Fixed Costs by Year[b]	Operating and Maintenance Costs by Year[a]	Total Annualized Compliance Costs by Year
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995			
	3.55	3.55	-	8.73	8.73	8.73	8.73	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26			
1978																			-	-	-
1979	.60																		.60	-	.60
1980	.60	.60																	1.20	1.00	2.20
1981	.60	.60	-																1.20	1.00	2.20
1982	.60	.60	-	1.48															2.68	1.00	3.68
1983	.60	.60	-	1.48	1.48														4.16	1.00	5.16
1984	.60	.60	-	1.48	1.48	1.48													5.64	6.50	12.14
1985	.60	.60	-	1.48	1.48	1.48	1.48												7.12	6.50	13.62
1986	.60	.60	-	1.48	1.48	1.48	1.48	.21											7.33	6.50	13.83
1987	.60	.60	-	1.48	1.48	1.48	1.48	.21	.21										7.54	6.50	14.04
1988	.60	.60	-	1.48	1.48	1.48	1.48	.21	.21	.21									7.75	6.50	14.25
1989	.60	.60	-	1.48	1.48	1.48	1.48	.21	.21	.21	.21								7.96	6.50	14.46
1990		.60	-	1.48	1.48	1.48	1.48	.21	.21	.21	.21	.21							7.57	6.50	14.07
1991			-	1.48	1.48	1.48	1.48	.21	.21	.21	.21	.21	.21						7.18	6.50	13.68
1992				1.48	1.48	1.48	1.48	.21	.21	.21	.21	.21	.21	.21					7.39	6.50	13.89
1993					1.48	1.48	1.48	.21	.21	.21	.21	.21	.21	.21	.21				6.12	6.50	12.62
1994						1.48	1.48	.21	.21	.21	.21	.21	.21	.21	.21	.21			4.85	6.50	11.35
1995							1.48	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21		3.58	6.50	10.08
1996								.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	2.31	6.50	8.81

Notes and Sources:
a. From Table V-11.
b. Reflect the following major assumptions: (1) capital recovery period of 11 years; (2) fixed charge coefficient of 0.17 (i.e., 17.0%); (3) capital outlays for pollution abatement replacement investment at 3% of total pollution abatement investment in place, taking place after the plant is in operation following the installation of the pollution abatement machinery and equipment under the various control options (i.e., starting in 1984 or 1985, depending on the control option).

TABLE V-16

ANNUALIZED COMPLIANCE COSTS AT ASARCO-TACOMA UNDER OPTION 4.2B
(CONTROL OPTION 4, WITH OSHA, BASE CASE), 1978-1996
(millions of 1978 dollars)

Years when fixed costs are faced	Years when pollution abatement capital expenditures (dollar outflows) takes place[a].																		Annualized Fixed Costs by Year[b]	Operating and Maintenance Costs by Year[a]	Total Annualized Compliance Costs by Year
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995			
	9.55	9.55	6.00	6.00	6.00	6.00	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29			
1978																			-	-	-
1979	1.62																		1.62	-	1.62
1980	1.62	1.62																	3.24	1.60	4.84
1981	1.62	1.62	1.02																4.26	2.20	6.46
1982	1.62	1.62	1.02	1.02															5.28	3.40	8.68
1983	1.62	1.62	1.02	1.02	1.02														6.30	4.60	10.90
1984	1.62	1.62	1.02	1.02	1.02	1.02													7.32	5.80	13.12
1985	1.62	1.62	1.02	1.02	1.02	1.02	.22												7.54	5.80	13.34
1986	1.62	1.62	1.02	1.02	1.02	1.02	.22	.22											7.76	5.80	13.56
1987	1.62	1.62	1.02	1.02	1.02	1.02	.22	.22	.22										7.98	5.80	13.78
1988	1.62	1.62	1.02	1.02	1.02	1.02	.22	.22	.22	.22									8.20	5.80	14.00
1989	1.62	1.62	1.02	1.02	1.02	1.02	.22	.22	.22	.22	.22								8.42	5.80	14.22
1990		1.62	1.02	1.02	1.02	1.02	.22	.22	.22	.22	.22	.22							7.02	5.80	12.82
1991			1.02	1.02	1.02	1.02	.22	.22	.22	.22	.22	.22	.22						5.62	5.80	11.42
1992				1.02	1.02	1.02	.22	.22	.22	.22	.22	.22	.22	.22					4.82	5.80	10.62
1993					1.02	1.02	.22	.22	.22	.22	.22	.22	.22	.22	.22				4.02	5.80	9.82
1994						1.02	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22			3.22	5.80	9.02
1995							.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22		2.42	5.80	8.22
1996								.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	2.42	5.80	8.22

Notes and Sources:
a. From Table V-11.
b. Reflect the following major assumptions: (1) capital recovery period of 11 years; (2) fixed charge coefficient of 0.17 (i.e., 17.0%): (3) capital outlays for pollution abatement replacement investment at 3% of total pollution abatement investment in place, taking place after the plant is in operation following the installation of the pollution abatement machinery and equipment under the various control options (i.e., starting in 1984 or 1985, depending on the control option).

cost schedules, thus directly affecting its financial performance and economic viability. How precisely compliance costs would affect Tacoma's production costs becomes, therefore, analytically important for economic impact analysis[1]. Compliance costs, serving generally as the central causal instrument, hence represent an input into economic impact analysis; compliance costs and economic impacts are, in this case, not synonymous.

In general, a custom smelter and refinery such as Tacoma can respond in five basic ways to incremental pollution abatement costs:

a. absorb the costs internally;

b. pass these costs back to the mines by increasing the smelting and refining charges;

c. pass the costs forward to purchasers of copper; and/or to purchasers of byproducts;

d. change raw materials (e.g., switch to low-impurity concentrates);

---

[1] For a review of how the cost schedules of a firm or an industry are affected by compliance costs, refer to Technical Appendix to Arthur D. Little report, Econometric Simulation and Impact Analysis Model of the U. S. Copper Industry, Supporting Paper 5: "Effects of Pollution Abatement and Control Costs on Industry-Wide Cost Functions".

As indicated here, in the short-term (e.g., a year), the case of pollution abatement cost impact is perfectly analogous to the case of a specific tax levied on the output of the firm (e.g., x cents per pound of refined copper) only in the restricted instance of an upward shift in the firm's total variable cost function. Consequently, the average variable cost (AVC), average total cost (ATC), and marginal cost schedules (curves, functions) shift upward by a constant.

However, in the case of pollution abatement and control capital investment only, average fixed cost (AFC) and ATC schedules shift upward (which increases in severity at lower levels of capacity), while the AVC and MC schedules are not affected.

If compliance costs involve both capital expenditures and variable costs, then assuming linear total cost, total fixed cost, and total variable cost functions, the AVC, MC, AFC and ATC schedules all shift upward; while AVC and MC shift upward by a constant, the shift in AFC and ATC becomes increasingly severe at lower levels of production. Given a typical downward-sloped demand schedule, these results have different implications for the firm's price-output determination behavior and therefore impact results, depending on market structure.

e. shut the plant down (e.g., parts of the Tacoma complex or the entire complex, and shift production to other plants) and recover working capital plus the salvage value of the equipment.

Of course, the first four of these response modes are not necessarily mutually exclusive.

Tacoma, as a producer of only about 7% of the U. S. copper, cannot selectively increase copper prices to cover increased costs. This largely eliminates option (c) above. The bulk of our economic impact analysis will therefore concentrate on the remaining options, based on both microeconomic and financial analysis.

It should be noted that Option (b) has been used by Asarco in the past. Starting in May 1970, Asarco instituted a pollution control surcharge of 1¢/lb. for copper prices less than or equal to 50¢/lb. and 1.5¢/lb. for higher prices. This arrangement applied to all shippers of concentrates to the three Asarco copper smelters (Tacoma, Hayden, and El Paso). This arrangement was used to finance pollution control at all three smelters. The arrangement was phased out at the end of 1975. As a result of this surcharge, Asarco lost a significant customer, Cyprus Mines and its production from the Pima and Bagdad Mines[1]. We understand that Cyprus now uses Phelps Dodge for smelting and refining their mine output.

An economic impact study of this type requires access to sensitive or confidential information at the plant level. On the other hand, since this is a public report, this confidential information can potentially be disseminated to a wide audience. Our approach has been to develop an understanding of Asarco's accounting structure and cost/allocation policies, based on several discussions with Asarco. Based on this we have projected into the future (1978-1995) estimates of Tacoma's variable and fixed costs and revenues. This estimate is on a 1978 basis in order to be consistent with PEDCo's cost basis.

Economic impacts are typically measured as differences from a set of baseline conditions. Baseline conditions broadly define the future environment that would be expected to prevail in the absence of certain regulations. With the regulations, because of increased costs of production due to compliance costs (plus the other effects of regulations, for example on capacity growth), the baseline conditions would be altered. The differences are attributed to the regulations. The baseline conditions hypothesized by us are discussed in detail in Chapter IV.

---

[1] Simon Strauss, op. cit., p. 479.

2. The Basic Approach

The basic approach taken in determining and assessing the impact of incremental pollution control was twofold: financial and microeconomic. The financial analyses were performed for the future operations at Tacoma, within an internally consistent microeconomic framework as to the customer base and revenues deriving therefrom. The financial analysis focused on the net present value of cash flows at Tacoma, treating Tacoma as a stand-alone business--i.e., a profit center within the Asarco accounting structure, with explicit recognition of costs directly assignable to the on-going conduct of Tacoma's business.

In effect, the objective of the analysis was to simulate Asarco decision-making with respect to investment and operating strategies appropriate for Tacoma, where Asarco would be confronted with the cash flow patterns resulting from a particular pollution control option. This clearly assumes that Asarco's decision would be based on these principles.

The presumption is that Asarco management represents risk-averse investors who seek to maximize the wealth and, hence, value of the firm by maximizing the present value of its expected future cash flows. Modern financial theory and managerial economics characterize this type of problem as one of investment decision-making under uncertainty. Within this classification, we are dealing with the simulated capital budgeting process at a particular firm--Asarco.

The techniques of capital budgeting employ several basic concepts, viz:
(1) There is a time value of money, such that a unit of money received today is worth more than one received at a later date, the difference being exactly equal to the return one can earn on the investment of the money until that date. In other words, one imputes value to money invested in accordance with the annual compound interest formula (or in certain cases, the continuous compounding formula).
(2) The present value PV(t) of a sum of money or cash flow $(CF)_t$ received _t_ years in the future is defined as and obtained from the discounting of that sum by the amount its present value would earn with compound interest at the discount rate, d. Thus,

$$(PV)_t = \frac{(CF)_t}{(1+d)^t}$$

For a sum of cash flows over a period N year

$$PV = \sum_{t=0}^{N} \frac{(CF)_t}{(1+d)^t}$$

The cash flows may be either positive (net receipts) or negative (net outlays). They may occur continuously or intermittently. In the analysis herein, cash flows are assumed to occur annually, with t=0 set at January 1, 1978. Thus, the present value of $1 received on that date would be exactly +$1, and of $1 spent on that date, exactly

-\$1. The present value of \$1 received on January 1, 1979 would be worth \$0.91 on January 1, 1978.

For economic analysis, all cash flows are first expressed in real terms in constant (1978) dollars. This, in effect, cancels the effect of inflation or the decrease in purchasing power.

The term Net Present Value, NPV, refers to the algebraic sum of the present value of cash investments (outlays) with the present value from future receipts generated from the business.

(3) The internal rate of return, d_I, from a set of cash flows is the discount rate which makes the net present value zero:

$$NPV = 0 \text{ for } \sum_{t=0}^{N} \frac{(CF)_t}{(1+d_I)^t}$$

(4) The so-called discounted cash flow (DCF) analyses employing PV and NPV implicitly assume that opportunities are in fact always available for reinvestment of the cash flows at the same rate as the discounted rate employed. (This is analogous to the concept employed in standard tables giving the present value of an annuity, bond yields to maturity, and so forth). However, by defining a minimum interest rate or opportunity cost, one can think in terms of a hurdle rate d_h, which is usually synonymous with the discount rate employed in new venture analysis. That is, projects are considered if they produce a rate of return greater than or equal to the hurdle rate.

(5) If there are no constraints on the size of the capital expenditures, i.e., if those considered do not require the firm to resort to unreasonable external financing, then capital budgeting decisions will be chosen from among a set of alternatives in order of increasing NPV for a given d_R, or in order of decreasing R for a given investment outlay.

(6) Other things equal, a strategy or option which involves positive cash returns to be received in the distant future is, by definition, riskier than one where such cash flows are received earlier. Also, by definition, a project whose cash flows are highly uncertain is riskier than one where they are predictable. An example of the first type is an investment in a new low-grade mine without any long-term contracts for its output; an example of the second would be a first mortgage on prime commercial property.

(7) Relatedly, investors must be compensated for incurring risk, so that, when comparing investment alternatives, the riskier the project, the higher must be its expected (<u>ex ante</u>) return. The concept of a risk-adjusted rate of return is thus employed to compare projects with different risk characteristics; this is facilitated by thinking in terms of a higher discount rate than the firm's opportunity cost of capital for projects which are significantly riskier than its average investment.

(8) Associated with the concept of a risk-adjusted discount rate is an additional concept: the excess return per unit of risk which is defined as the expected return minus the risk free rate of interest, divided by the standard deviation of the returns realized from similar projects.

The excess return, ρ, is also called the risk premium. Thus, if r denotes the risk free rate of interest, the appropriate discount rate to use incorporates the risk premium:

$$d = \rho + r.$$

(For an investment in U. S. Treasury obligation, ρ is equal to zero.)

Given equilibrium conditions in the economy and the capital markets, a firm will earn at a rate d on its investments, and d will be equal to its cost of new capital.

The presumption is that for rational, risk-averse investors, the expected return on any equity or industrial investment is always greater than the risk-free rate of interest (i.e., U. S. Treasury obligations). It is assumed that the decisions of a firm reflect the wealth-maximizing behavior of risk-averse investors, and it is assumed that transactions in the capital markets result in costs of capital to the firm which reflect the risk-return characteristics of its securities.

Turning now to the alternatives facing Asarco at Tacoma, the approach was to calculate the net present value of Tacoma's cash flow under various scenarios, starting with baseline conditions and continuing with variations on the baseline conditions. The NPV's of different options were obtained by superposition of the incremental capital expenditures and O&M costs associated with the option. The NPV's of each option were also noted vis-á-vis the NPV of two boundary conditions, viz: (1) the continuation of Tacoma "as is" under baseline cash flow and no incremental environmental control costs, and (2) shutdown of Tacoma.

The presumption with respect to the first comparision is that Asarco management will strive for revenue conditions under incremental environmental control which restore Tacoma to a baseline cashflow condition. The presumption with respect to the second comparision is that, from the standpoint of financial criteria at least, and given no hope of condition (1), Asarco will tend to consider shutting down Tacoma if the net present value of the option appears to be less than the present value associated with shutdown. Formally, the following inequality

$$\left[\sum_{t=0}^{\infty} \frac{(C.F.)_t}{(1+d)^t}\right]_{\text{Option}} - \left[\sum_{t=0}^{\infty} \frac{(C.F.)_t}{(1+d')^t}\right]_{\text{shutdown}} >> 0$$

must hold, to unambiguously keep Tacoma operating under the posited pollution control option conditions.

Note that in the above formulation, the time horizon is infinite. In actual calculations, the series of terms was truncated at the year 1995, a procedure which introduces little error at the discount rates employed, and, in any case, one which closely approximates the type of projection that might be used in industry.

The discount rate, d′, under a shutdown scenario, denotes that there could be a difference in the degree of cash flow uncertainty, and hence, risk, as perceived by Asarco, between the alternatives. We have assumed this difference to be minor, i.e.,

$$d_{\text{option}} \approx d_{\text{shutdown}}$$

As developed and discussed in the next section, we have used discount rates of 10% and 15% on an after-tax basis in computing NPV's.

3. Asarco's Cost of Capital and Estimated Hurdle Rate for Tacoma

In computing the present value of alternative investment strategies, an appropriate discount rate to use is the corporation's perception of its risk-adjusted opportunity cost of equity capital. It is never easy to establish this with precision. For this reason, we have used several different approaches for estimating the hurdle rate or the appropriate discount factor for evaluating alternative courses of action at Tacoma.

- Asarco's historical performance: The nonferrous metals business is highly cyclical and erratic and is hence considered risky. We believe Asarco's management, like that of other metals/mining companies, traditionally used an *ex ante* equity rate of return criterion, or hurdle rate, of 12-15% for evaluating investments of *average risk* in the business and economic environment of the 1960's when inflation was 3% or less. (This implies a hurdle rate in constant dollar terms of 9%-12%.) For the period 1965-1976 inclusive Asarco realized long-term return on equity of 12-13%, in current dollars. However, for the last five years, its return was only about 9-1/2%. (If the recession year 1975 is eliminated Asarco's return for the latter period was 11% on average). When one adjusts this return for inflation, the result is that the *ex post* real rate of return achieved was only 5%. In 1976 Asarco's corporate-wide return on total capital employed was 6%. In a "normal" year, we estimate Asarco's total earnings would be higher and interest charges lower than in 1976 and that return on total capital would be 7-8%.

Under baseline conditions of Chapter IV, we estimate that Tacoma would earn on average approximately $1.78 million net after taxes (in 1978 dollar terms) and be responsible for $1.5 million per year in interest payments. We estimate the related sum of Tacoma net plant and working capital to be $44.3 million, so that return on total capital would be about 7.4%. Thus, our estimate for Tacoma is higher than Asarco's present return, and comparable to Asarco's overall expected return on capital.

Today, high grade bonds are available which yield 7-9% pre-tax, and high grade preferred stocks are available which yield about 7.5% after-tax. Stockholders of Asarco by definition are risking all or a portion of their wealth in the expectation of earning more than the returns available on these relatively risk-free investments. Thus we think Asarco management and stockholders today think in terms of a hurdle rate greater than the return allowed regulated electric utilities, who are being allowed 12-3/4-16% return on equity[1]. In real terms, with 5% expected inflation, this suggests to us a minimum Asarco hurdle rate of 10% (in constant dollars) and an average hurdle rate of 15%, which would apply to investments of normal business risk to Asarco.

- Cost of New Equity Capital: Besides Asarco's own hurdle rate, another measure is the market cost of new equity capital. This may be approximated by the reciprocal of the price-to-earnings ratio on its stock. (Still another model, appropriate for a stock whose earnings grow at a predictable rate and whose dividend payout is constant, is the sum of the dividend yield plus the growth rate[2]). Note for comparison that the P/E equivalent for a bond today is about 1/8 or 12.5%; thus, one might expect stocks of companies like Asarco to command a P/E ratio less than that on a bond. Indeed, the median P/E ratio of Value Line Investment Survey's broad list of stocks is about 8.0. And, using the 5-year average earnings for Asarco as a proxy for its earning power, the P/E for Asarco today would be about:

$$\frac{\$20/\text{share}}{\dfrac{\$67 \text{ million average earnings per year}}{26.7 \text{ million shares}}} = 8$$

---

[1]See, for example, Blyth Eastman Dillon & Co., Inc., Investment Research "Electric Utilities Market Service", Volume V, No. 2, April 1977; and Testimony of Mr. Eugene Meyer of Kidder Peabody & Co., Docket 761-8, New Jersey Board of Public Utility Commissioners, 1976.

[2]See Weston and Brigham, "Managerial Finance", Chapter 12, Third Edition, 1969 (Holt Rinehart & Winston).

Thus, if the above calculation accurately reflected investor perceptions, Asarco's cost of new equity would be about 1/8 = 12.5% in current dollar terms. With 5% inflation, the constant dollar cost would be about 7.5%.

The Value Line Investment Survey, a well regarded investment service, has estimated 1977 earnings per share for Asarco which translate into a current P/E of 6-7; this would be equivalent to a cost of capital of 14-16%. (Alternatively, using the second model of dividend yield plus growth, with Value Line estimates of average future earnings growth about 6% per year and "normal" dividends of 6.2%, the equivalent idealized cost of capital in a future environment would then be 12-13%).

- New projects versus on-going businesses: We believe that for new, risky projects the after-tax hurdle rate to be employed in present value/rate of return analyses re Tacoma should be greater than the inflation-adjusted after-tax cost of equity capital associated with the normal, on-going diversified business of Asarco as a whole. Thus, we have used 10% as the minimum constant dollar hurdle rate, and 15% as a more representative rate.

  It should be noted that Asarco and other nonferrous metals companies have made significant use of tax-exempt pollution control revenue bond financing. However, the possibility of pollution control bond financing at Tacoma to lower the cost of capital is foreclosed because the State of Washington has disallowed this type of financing[1].

4. Illustrative Example

Table V-17 illustrates the calculation of the NPV associated with Control Option 4.2B (minimum control, with OSHA) under baseline revenue conditions. The calculation is done year-by-year to obtain each year's net cash flow after taxes. The algebraic sum of all cash flows is discounted year-by-year to compute the net present values (under two different discount rate assumptions) from operations over the period 1978-1995.

Tacoma's revenues are shown in column 2. Baseline revenues of $49 million were used throughout the period. The capital expenditures are shown in column 3. The year-by-year operations and maintenance costs in column 4, are for both the baseline and for incremental pollution control.

---

[1]See Port of Longview vs. Taxpayers of same, 84 Washington, 2d 475,527, p. 2d 263 (1974); Opinion and Modified Rehearing Denied, 85 Washington, 2d 216,533, p. 2d 128 (1975).

TABLE V-17

CONTROL OPTION 4.2B (MINIMUM CONTROL, WITH OSHA) AFTER-TAX CASH FLOW ANALYSIS UNDER BASELINE REVENUE CONDITIONS
(in millions of 1978 dollars)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
								Net Federal Tax[h]		After-Tax Profit[h]		Cash Flow After Tax[h]	
Years	Revenues	Capital Expenditures[a]	O&M Cost Plus G&A[b]	Depreciation (Accelerated)[c]	Pre-Tax Profits	Federal Tax @ 48%[d,h]	ITC[e,h]	With Parent[f]	Stand Alone[g]	With Parent[f]	Stand Alone[g]	With Parent[f]	Stand Alone[g]
1978	49.0	10.75	44.5	1.20	3.30	1.58	(.54)	1.04	1.04	2.26	2.26	-7.29	-7.29
1979	49.0	10.75	44.5	2.94	1.56	.75	(54)	.21	.21	1.35	1.35	-6.46	-6.46
1980	49.0	7.20	46.1	4.36	-1.46	(.70)	(.36)	(1.06)	(1.06)	(.40)	(.40)	-3.24	-3.24
1981	49.0	7.20	46.7	4.99	-2 69	(1.29)	(.36)	(1.65)	(.19)	(1.04)	(2.50)	-3.25	-4.71
1982	49.0	7.20	47.9	5.60	-4.50	(2.16)	(.36)	(2.52)	-0-	(1.98)	(4.50)	-3 58	-6.10
1983	49.0	7.20	49.1	6.11	-6.21	(2.98)	(.36)	(3.34)	-0-	(2.87)	(6.21)	-3.96	-7.30
1984	49.0	2.46	50.3	6.53	-7.83	(3.76)	(.12)	(3.88)	-0-	(3.95)	(7.83)	-1.20	-3.76
1985	49.0	2.46	50.3	6.02	-7.32	(3.51)	(.12)	(3.63)	-0-	(3.69)	(7.32)	-1.3	-3.76
1986	49.0	2.46	50.3	5.59	-6.89	(3.31)	(.12)	(3.43)	-0-	(3.46)	(6.89)	- .33	-3.76
1987	49.0	2.46	50.3	5.13	-6.43	(3.09)	(.12)	(3.21)	-0-	(3.22)	(6.43)	- .55	-3.76
1988	49.0	2.46	50.3	4.65	-5.95	(2.86)	(.12)	(2.98)	-0-	(2.97)	(5.95)	- .78	-3.76
1989	49.0	2.46	50.3	4.14	-5.44	(2.61)	(.12)	(2.73)	-0-	(2.71)	(5.44)	-1.03	-3.76
1990	49.0	2.46	50.3	3.61	-4.91	(2.36)	(.12)	(2.48)	-0-	(2.43)	(4.91)	-1.28	-3.76
1991	49.0	2.46	50.3	3.21	-4.51	(2.16)	(.12)	(2.28)	-0-	(2.23)	(4.51)	-1.48	-3.76
1992	49.0	2.46	50.3	2.93	-4.23	(2.03)	(.12)	(2.15)	-0-	(2.08)	(4.23)	-1.61	-3.76
1993	49.0	2.46	50.3	2.72	-4.02	(1.93)	(.12)	(2.05)	-0-	(1.97)	(4.02)	-1.71	-3.76
1994	49.0	2.46	50.3	2.58	-3.88	(1.86)	(.12)	(1.98)	-0-	(1.90)	(3.88)	-1.78	-3.76
1995	49.0	2.46	50.3	2.51	-3.81	(1.83)	(.12)	(1.95)	-0-	(1.86)	(3.81)	-1.81	-3.76
								Summary: NET PRESENT VALUE					
										@ 10%		-$25.5	-$40.0
										@ 15%		-$21.3	-$31.1

Notes:
a. Includes capital expenditures required under this control option plus annual replacement investment on basic plant and equipment (i.e , $1.2 million/year) regardless of any control option.
b. Operating and maintenance costs plus general and administrative expenses (baseline) plus operating and maintenance costs required under the control option considered.
c. Calculated by using an accelerated depreciation schedule (refer to the text and associated tables for further detail).
d. Federal corporate income tax liability, computed at an assumed marginal rate of 48 percent against pre-tax profits.
e. Income tax credit, estimated at 5% of total capital expenditures in each accounting period (refer to the text for explanation, refer to footnote "h" below for the interpretation of figures given in parentheses).
f. Assumes that tax credits associated with ITC and/or losses at Tacoma will be utilized by the parent company (Asarco, Inc.) as offsets against its corporate income tax liability in its consolidated income tax return.
g. Assumes that tax credits from continuing losses at Tacoma will not be utilized by the parent company (Asarco, Inc.) as offsets against its corporate income tax liability.
h. Figures in parentheses indicate tax offsets

Column 5 presents the depreciation schedule assumed. In this case, 11-year accelerated depreciation was used for calculating income taxes. This schedule is shown in Table V-18. A sensitivity analysis was performed to compare accelerated depreciation and straight-line depreciation. Table V-19 shows the depreciation schedule when straight line depreciation is used. This latter approach results in a higher tax liability, other things equal, and thus reduces after-tax (but not pre-tax) cash flows by $0.48 per dollar of incremental depreciation. A comparison of the two depreciation methods and their effect on NPV is shown in Table V-20. Because the effect of the depreciation method was minor on a present value basis (and easily computed in the event the results of an option were ambiguous), the calculations for the remaining options were done using straight-line depreciation.

Column 6 computes the pre-tax profit by year, by subtracting costs and depreciation from revenues. Column 7 computes federal income tax liability using a 48% marginal tax rate.

The investment tax credit (ITC) in column 8 is subtracted from the taxes in column 7 to yield the net federal tax shown in columns 9 and 10. The ITC was computed with the assumption that 50% of the capital expenditures made in each year (in column 3) would qualify for a tax credit equal to 10% of the expenditure.

Columns 9 through 14 present calculations on two different tax bases, i.e., "With Parent" and "Stand Alone". The meaning of this is as follows:

"With Parent" assumes that any tax credits arising from operating losses and/or the ITC for Tacoma will be utilized as offsets by the parent, Asarco, Inc., in computing its tax liability when filing a consolidated federal income tax return. "Stand Alone" connotes Tacoma being assessed as a separate profit center and assumes that tax credits from any continuing operating losses at Tacoma and excess ITC credits will not be utilized by the parent company Asarco, Inc. (In accordance with the current provisions of the Internal Revenue Code, the ITC and operating losses can be carried back 3 years or carried forward 7 years in computing tax liability). Columns 11 and 12 show after-tax profit, subtracting columns 9 and 10, respectively from column 6.

Columns 13 and 14 compute cash flow after taxes, which is obtained by adding depreciation to the after-tax profits, and subtracting the capital expenditures in the same year from the result. In these calculations, all cash flows in a year are assumed to occur at the end of the year.

The annual net cash flows $(CF)_t$ were discounted at two different rates, 10% and 15%, which represent the estimated range for the cost of capital associated with the investments. The sum of these discounted cash flows equals the net present value shown at the bottom of the table.

TABLE V-18

ESTIMATED DEPRECIATION SCHEDULE FOR TACOMA, 1978-1995, FOR CONTROL OPTION 4.2B (MINIMUM CONTROL, WITH OSHA), UNDER THE 11-YEAR ACCELERATED DEPRECIATION APPROACH[a]

(in millions of 1978 dollars)

Years when depreciation is faced	BASE[b]	Years when pollution abatement capital expenditures (dollar outflows) take place																		TOTAL Depreciation
		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	
		9.55	9.55	6.00	6.00	6.00	6.00	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	
1978	1.20[c]	-																		1.20[c]
1979	1.20	1.74	-																	2.94
1980	1.20	1.42	1.74	-																4.36
1981	1.20	1.28	1.42	1.09	-															4.99
1982	1.20	1.14	1.28	.89	1.09	-														5.60
1983	1.20	.99	1.14	.80	.89	1.09	-													6.11
1984	1.20	.85	.99	.71	.80	.89	1.09	-												6.53
1985	1.20	.71	.85	.62	.71	.80	.89	.24	-											6.02
1986	1.20	.57	.71	.54	.62	.71	.80	.20	.24	-										5.59
1987	1.20	.43	.57	.45	.54	.62	.71	.17	.20	.24	-									5.13
1988	1.20	.29	.43	.36	.45	.54	.62	.15	.17	.20	.24	-								4.65
1989	1.20	.14	.29	.27	.36	.45	.54	.13	.15	.17	.20	.24	-							4.14
1990	1.20	-	.14	.18	.27	.36	.45	.12	.13	.15	.17	.20	.24	-						3.61
1991	1.20			.09	.18	.27	.36	.10	.12	.13	.15	.17	.20	.24	-					3.21
1992	1.20				.09	.18	.27	.08	.10	.12	.13	.15	.17	.20	.24	-				2.93
1993	1.20					.09	.18	.06	.08	.10	.12	.13	.15	.17	.20	.24	-			2.72
1994	1.20						.09	.04	.06	.08	.10	.12	.13	.15	.17	.20	.24	-		2.58
1995	1.20							.02	.04	.06	.08	.10	.12	.13	.15	.17	.20	.24	-	2.51

Notes: a. The depreciation schedule used reflects "double declining balance" (DDB) over the first two years, then "sum of the years' digits" (SOYD) remaining life, given below. (The figures below are in percent of original cost);

Start Value	11 years life 100.00	Remainder
Year 1	18.18	81.82
2	14.88	66.94
3	13.39	53.55
4	11.90	41.65
5	10.41	31.24
6	8.93	22.31
7	7.44	14.88
8	5.95	8.93
9	4.46	4.46
10	2.98	1.49
11	1.49	0.00

Note: Capital expenditures incurred in a given accounting period start being depreciated in the following period.

b. Tacoma's base depreciation is assumed at $1.2 million/year, in equilibrium, associated with replacement investment to keep the basic plant and equipment in operation, regardless of the various control options. In equilibrium, replacement investment is assumed to equal depreciation.

c. Reflects capital expenditures for replacement incurred the previous year (i.e., 1977).

TABLE V-19

ESTIMATED DEPRECIATION SCHEDULE FOR TACOMA, 1978-1995, FOR CONTROL OPTION 4.2B (MINIMUM CONTROL, WITH OSHA), UNDER THE 11-YEAR STRAIGHT-LINE DEPRECIATION APPROACH[a]
(millions of 1978 dollars)

Years when depreciation is faced	BASE[b]	Years when pollution abatement capital expenditures (dollar outflows) take place																		TOTAL Depreciation
		1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	
		9.55	9.55	6.00	6.00	6.00	6.00	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	1.29	
1978	1.20[c]																			1.20[c]
1979	1.20	0.88																		2.08
1980	1.20	0.88	0.88																	2.98
1981	1.20	0.88	0.88	0.55																3.51
1982	1.20	0.88	0.88	0.55	0.55															4.06
1983	1.20	0.88	0.88	0.55	0.55	0.55														4.61
1984	1.20	0.88	0.88	0.55	0.55	0.55	0.55													5.16
1985	1.20	0.88	0.88	0.55	0.55	0.55	0.55	0.12												5.28
1986	1.20	0.88	0.88	0.55	0.55	0.55	0.55	0.12	0.12											5.40
1987	1.20	0.88	0.88	0.55	0.55	0.55	0.55	0.12	0.12	0.12										5.52
1988	1.20	0.88	0.88	0.55	0.55	0.55	0.55	0.12	0.12	0.12	0.12									5.64
1989	1.20	0.88	0.88	0.55	0.55	0.55	0.55	0.12	0.12	0.12	0.12	0.12								5.76
1990	1.20		0.88	0.55	0.55	0.55	0.55	0.12	0.12	0.12	0.12	0.12	0.12							5.00
1991	1.20			0.55	0.55	0.55	0.55	0.12	0.12	0.12	0.12	0.12	0.12	0.12						4.24
1992	1.20				0.55	0.55	0.55	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12					3.81
1993	1.20					0.55	0.55	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12				3.38
1994	1.20						0.55	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12			2.95
1995	1.20							0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12		2.52

Notes:
a. Computed by dividing each year's pollution control capital expenditures by 11; capital expenditures incurred in a given accounting period; start being depreciated in the following period.
b. Tacoma's base depreciation is assumed at $1.2 million/year, in equilibrium, associated with replacement investment to keep the basic plant and equipment in operation, regardless of the various control options. In equilibrium, replacement investment is assumed to equal depreciation.
c. Reflects capital expenditures for replacement incurred the previous year (i.e., 1977).

TABLE V-20

DEPRECIATION ESTIMATES FOR TACOMA UNDER CONTROL OPTION 4.2B (MINIMUM CONTROL, WITH OSHA): DIFFERENCES BETWEEN RESULTS OBTAINED BY USING ACCELERATED AND STRAIGHT-LINE METHODS

(millions of 1978 dollars)

Years	Depreciation		Difference in Tax Benefit to Tacoma[a]	Present Value at Discount Rate of	
	Accelerated	Straight-line		10%	15%
1979	2.94	2.08	.41	.34	.31
1980	4.36	2.96	.67	.50	.44
1981	4.99	3.51	.71	.48	.41
1982	5.60	4.06	.74	.46	.37
1983	6.11	4.61	.72	.41	.31
1984	6.53	5.16	.66	.34	.25
1985	6.02	5.28	.36	.17	.12
1986	5.59	5.40	.09	.04	.03
1987	5.13	5.52	-.19	-.07	-.05
1988	4.65	5.64	-.48	-.17	-.10
1989	4.14	5.76	-.78	-.25	-.15
1990	3.61	5.00	-.67	-.19	-.11
1991	3.21	4.24	-.49	-.13	-.07
1992	2.93	3.81	-.42	-.10	-.05
1993	2.72	3.38	-.32	-.07	-.03
1994	2.58	2.95	-.18	-.03	-.02
1995	2.51	2.52	-.005	- 0	0

Summary: PRESENT VALUE OF THE DIFFERENCE IN TAX BENEFIT AT
10% DISCOUNT RATE: $1.73 million
15% DISCOUNT RATE: $1.66 million

Notes: a. The difference in federal corporate income tax benefit is computed as follows:

$$\Delta B_t = 0.48\, D_t^a - 0.48\, D_t^s$$
$$= 0.48\, (D_t^a - D_t^s)$$

where

ΔB_t : difference in tax benefit in year t;

D_t^a : accelerated depreciation in year t;

D_t^s : straight-line depreciation in year t;

0.48 : the assumed, marginal tax rate.

It should be noted that these calculations were assumed to be relevant only over a finite period, i.e., 1978-1995 inclusive. This span is relatively long for business planning under conditions of uncertainty, and were the calculations to be extended further, it would be appropriate to consider raising the discount rate to reflect greater risk associated with the outcome.

Implicit in this methodology is the assumption that Tacoma would continue operations beyond 1995 but given the discount rates the present value of future cash flows beyond 1995 is sufficiently small and can be ignored. An alternative approach would have been to assume that the plant is shut down at the end of this period of analysis and to add in the salvage value of the plant. The salvage value in 1996 would not vary much from option to option and would result in a small, constant offset in the net present values shown here. For example, the net present value of $20 million in 1996 is only $1.4 million at a 15% discount rate, whereas, the net present value for option 4.2B is $-21 to $-31 million at the same discount rates.

E. CASH FLOW ANALYSIS OF INCREMENTAL POLLUTION CONTROL OPTIONS UNDER BASE CONDITIONS

We present, in this section, a cash flow analysis of the various incremental pollution control options under base conditions. We first present a recapitulation of base conditions, followed by our analysis and conclusions.

1. Recapitulation of Base Conditions

Very briefly, the base conditions assume annual production of 100,000 short tons of refined copper, all derived from Tacoma-produced blister (i.e., the smelter and refinery production levels are the same). Tacoma's effective productive capacity is determined by its ability to process sulfur-bearing materials. Tacoma's feedstock sources consist of "clean" concentrates, i.e., Duval and other southwestern suppliers, "dirty" concentrates, i.e., Lepanto; Northern Peru, and, East Helena. In addition, Tacoma is assumed to process a large amount of precipitates and scrap. Metallurgical conditions at Tacoma require a mix of "dirty" and "clean" feedstocks roughly in the ratio indicated by the baseline materials mix.

Asarco-Tacoma is primarily a copper smelter/refiner, deriving its revenues mainly by providing smelting/refining services essentially on a toll basis. Its byproduct revenues, assumed at $3.6 million/year, comprise a small fraction of its total "base" revenues of about $49.0 million/year, estimated at an average smelting/refining toll rate of 22.7¢/lb. This assumes that Tacoma will continue to follow a "contractual pricing" approach during this period, as in the past and Tacoma's toll covers its processing costs and allows for a normal profit margin. This assumed toll rate reflects anticipated cost conditions in 1978 and beyond and allows for pretax profits of about $3.3 million/year at Tacoma, which amounts to roughly a 6.7% rate of return on total sales, higher than that for Asarco as a whole in recent years. If, alternatively, Tacoma were to set a toll rate consistent with a given target rate of return on total sales, say at 10% of total sales, neither the assumed toll rate nor the resulting profit margin are altered significantly. At any rate, the effect of such variations in baseline toll rate, profit, revenue, etc., on our impact conclusions under the various control options is examined in detail in Section G.

The assumed toll rate of 22.7¢/lb. is also broadly congruent with long-run copper floor prices at around 80¢/lb., such that, under these copper price and toll conditions, all of Tacoma's suppliers would be expected to continue remaining in business as they would cover their long-run costs, including a "normal" rate of return on investment.

2. Analysis

The same methodology illustrated for Option 4.2B previously has been used for analyzing the economic impact of other control options on Tacoma under baseline conditions. These options are:

- Option 4.1B: Minimum SO_2 control (1978-1979); particulate control (1978-1979)
- Option 3.1B: Minimum SO_2 control (1978-1979); particulate control (1978-1979); roaster gas enrichment--acid plant consolidation
- Option 3.2B: Option 3.1B plus OSHA (1978-1983)
- Option 1.1B: Maximum SO_2 control (1980-1983); particulate control (1978-1979)
- Option 1.2B: Option 1.1B plus OSHA (1978-1983)

In each case, year-by-year cash flows were estimated including the investment tax credit and the net present value of these cash flows was calculated at discount rates of 10% and 15%. Tables V-21 and V-22 respectively present the net after-tax cash flows for each alternative under "with parent" and "stand alone" assumption. Table V-23 summarizes these results. Fundamentally, the net present value approach requires the comparison of net present values of alternative courses of action. Since one such alternative is to shut down Tacoma, Table V-23 also includes the net present value of this shut down alternative. This alternative is discussed in detail in Section F.

TABLE V-21

SUMMARY OF AFTER-TAX CASH FLOW ANALYSIS RESULTS FOR THE VARIOUS CONTROL OPTIONS EXAMINED WHERE TACOMA IS CONSIDERED AS PART OF THE PARENT COMPANY, ASARCO, INC.[a,b]

(after-tax cash flow, in millions of 1978 dollars)

Years	Option 4.1B-Minimum, No OSHA	Option 4.2B-Minimum With OSHA	Option 3.1B-Intermediate; Delay; No OSHA	Option 3.2B-Intermediate; Delay; With OSHA	Option 1.1B-Maximum No OSHA	Option 1.2B-Maximum With OSHA
1978	- 1.59	- 7.29	- 1.59	- 7.29	- .88	- 6.6
1979	- 1.44	- 6.46	- 1.44	- 6.88	- .76	- 6.2
1980	1.35	- 3.24	1.56	- 3.92	-11.7	-17.2
1981	1.36	- 3.25	- 6.73	-12.3	-11.1	-16.6
1982	1.37	- 3.58	- 6.35	-12.2	-10.5	-16.4
1983	1.38	- 3.96	- 5.97	- 6.5	- 9.9	-16.1
1984	1.39	- 1.20	- 8.45	- .7	- .8	- 2.6
1985	1.40	- 1.30	- 0.98	- 3.4	- .7	- 2.6
1986	1.41	- 0.33	- 0.93	- 3.4	- .5	- 2.5
1987	1.42	- 0.55	- 0.87	- 3.3	- .5	- 2.5
1988	1.43	- 0.78	- 0.78	- 3.2	*	*
1989	1.44	- 1.03	- 0.77	*	*	*
1990	1.30	- 1.28	- 0.87	*	*	*
1991	1.15	- 1.48	- 0.97	*	*	*
1992	1.15	- 1.61	- 0.92	*	*	*
1993	1.15	- 1.71	- 1.24	*	*	*
1994	1.15	- 1.78	- 1.57	*	*	*
1995	1.15	- 1.81	- 1.90	*	*	*

* Year-by-year details omitted

Summary						
NET PRESENT VALUE						
@10%	6.1	-25.5	-21.1	Min.[c] - 41	Min.[c] - 32	Min.[c] - 60
@15%	3.6	-21.3	-16.2	Min.[c] - 34	Min.[c] - 26	Min.[c] - 50

Notes:

a. Assumes that tax credits' associated with ITC and/or losses at Tacoma will be utilized by the parent company (Asarco, Inc.) and offsets against its corporate income tax liability in its consolidated income tax return.

b. The results presented in this table have been obtained by performing the same computations reported in connection with Option 4.2B presented earlier to provide an example. It should be noted that whereas the results given for Option 4.2B reflect the use of accelerated depreciation the results given for all other options involve the use of straight-line depreciation. It will be recalled from a discussion given earlier that the use of one or the other method of estimating depreciation has little effect on the results.

c. The net present value figures shown here represent the most optimistic outcomes (i.c., if the net present value figures are computed more fully, beyond the certain number of year considered here, the results would be even more negative).

TABLE V-22

SUMMARY OF AFTER-TAX CASH FLOW ANALYSIS RESULTS FOR THE VARIOUS CONTROL OPTIONS EXAMINED WHERE TACOMA IS CONSIDERED ON A STAND-ALONE BASIS[a,b]

(after-tax cash flow, in millions of 1978 dollars)

Years	Option 4.1B-Minimum, No OSHA	Option 4.2B-Minimum, With OSHA	Option 3.1B-Intermediate; Delay, No OSHA	Option 3.2B-Intermediate; Delay; With OSHA *	Option 1.1B-Maximum; No OSHA *	Option 1.2B-Maximum; With OSHA *
1978	- 1.59	- 7.29	- 1.59			
1979	- 1.44	- 6.46	- 1.44			
1980	1.35	- 3.24	1.56			
1981	1.36	- 4.71	- 6.73			
1982	1.37	- 6.10	- 6.35			
1983	1.38	- 7.30	- 5.97			
1984	1.39	- 3.76	-10.24			
1985	1.40	- 3.76	- 4.46			
1986	1.41	- 3.76	- 4.46			
1987	1.42	- 3.76	- 4.46			
1988	1.43	- 3.76	- 4.46			
1989	1.44	- 3.76	- 4.46			
1990	1.30	- 3.76	- 4.46			
1991	1.15	- 3.76	- 4.46			
1992	1.15	- 3.76	- 4.46			
1993	1.15	- 3.76	- 4.46			
1994	1.15	- 3.76	- 4.46			
1995	1.15	- 3.76	- 4.46			
				* Year-by-year details omitted		
Summary:						
NET PRESENT VALUE						
@10%	6.1	-40.0	-33.5	Min.[c] - 41	Min.[c] - 32	Min.[c] - 60
@15%	3.6	-31.0	-23.7	Min.[c] - 34	Min.[c] - 26	Min.[c] - 50

Notes:
a. Assumes that continuing losses at Tacoma will not be utilized, on a continuous basis, by the parent company (Asarco, Inc.) as tax credits (offsets) against its corporate income tax liability.
b. The results presented in this table have been obtained by performing the same computations reported in connection with Option 4.2B presented earlier to provide an example. It should be noted that whereas the results given for Option 4.2B reflect the use of accelerated depreciation the results given for all other options involve the use of straight-line depreciation. It will be recalled from a discussion given earlier that the use of one or the other method of estimating depreciation has little effect on the results.
c. The net present value figures shown here represent the most optimistic outcomes (i.e., if the net present value figures are computed more fully, beyond the certain number of years considered here, the results would be even more negative).

TABLE V-23

ESTIMATED NET PRESENT VALUES: POLLUTION CONTROL SUPERIMPOSED ON BASELINE CONDITIONS[a]

(in millions of 1978 dollars)

Options Considered	Net Present Value at Discount Rate of 10%	15%
4.1B (Minimum control, no OSHA)	+6	+4
4.2B (Minimum control, with OSHA)	-26 to -40	-21 to -31
3.1B (Intermediate; delay, no OSHA)	-21 to -36	-16 to -24
3.2B (Intermediate; delay; with OSHA)	Min. - 41	Min. - 34
1.1B (Maximum control; no OSHA)	Min. - 32	Min. - 26
1.2B (Maximum control, with OSHA)	Min. - 60	Min. - 50
Tacoma Shutdown	← +17 to +20 →	

Notes: See Tables V-20 and V-21

3. Conclusions

Tables V-21 through V-23 indicate that Option 4.1B is the only one for which there is a significant positive net present value. However, when compared with shutdown, (Table V-23), it cannot be stated that Option 4.1B would be unambiguously preferred over shutdown. All other options have relatively large negative NPV's and suggest without much ambiguity that a shutdown decision would be preferred, if financial criteria alone are the test.

It might be argued that Tacoma's revenues would be influenced by changes in market conditions facing Tacoma and its suppliers. This would be especially true if copper prices rise well above 80¢/lb. (in 1978 prices) for any reason such as a domestic smelter capacity bottleneck scenario for the next five to seven years. In such a situation, it is theoretically possible for Tacoma to follow a discriminatory monopolistic pricing strategy, pushing each mine/supplier to the limit, to maximize its smelting/refining revenues. Some of Tacoma's suppliers (e.g., Lepanto and Northern Peru) are highly dependent upon Tacoma in the short-term (i.e., 1978-1980). Overall, these suppliers have other alternatives: the suppliers of clean concentrates can switch to Japan in the short and the long-term if Tacoma's prices exceed certain "trigger" prices. The suppliers of impure concentrates can switch to the new Philippines smelter expected to start operations in 1981 or they can exercise the option of closing down, if they are unable to cover their variable costs. Hence there are limits to Tacoma's pricing behavior, even if it were to follow a discriminatory monopolistic pricing strategy. This is why we have chosen to start with "baseline" conditions which best reflect normal pricing behavior, and the normal relationship between a toll smelter/refinery and its suppliers that is consistent with long-run considerations which basically or typically govern the decisions and interrelationships of the nonferrous metals companies. Also, historically, individual smelters/refiners, having very little, if any, influence on copper prices, may understandably not have followed a monopolistic pricing strategy, not knowing, ex ante, what the copper price would exactly be over the next contract cycle. Given the wide band of variability in copper prices in the future, it is hazardous to hypothesize a unique set of revenue forecasts for Tacoma under one or another assumed pricing strategy on the part of Tacoma. With these considerations in mind, we have nonetheless performed a series of sensitivity analyses under hypothesized discriminatory monopolistic pricing behavior on the part of Tacoma, to explore a reasonably large range of possibilities.

F. SHUTDOWN

If Tacoma could continue operating under the 1978 baseline conditions in perpetuity, it would yield net cash flow equal to about $3.0 million per year after taxes. At a discount rate of 10%, the present value of this cash flow would be about $30 million; at 15%, it would be about $20 million. When incremental pollution control is required, the continuation of the baseline operation in perpetuity is no longer a viable alternative. The plant has to comply with this requirement either by spending funds for pollution control equipment or by closing the plant down. Thus should Asarco-Tacoma perceive the costs and uncertainties associated with continued operation of Tacoma to be too high in comparison with the revenues which may be expected, it would be expected to analyze the consequences of a shutdown. Indeed, Asarco has shutdown many plants in the past for economic reasons, e.g., the Murray, Leadville and Selby lead smelters, Selby lead refinery, Amarillo zinc smelter and the Baltimore and Perth Amboy copper refineries. Thus, this would not be the first time that Asarco has faced a decision of this type.

We have attempted to estimate the financial consequences of shutting down Tacoma as one alternative open to Asarco and have estimated the net present value of such an approach for comparison.

In general, the metals in process (metals in the "pipeline") would be released upon shutdown of Tacoma. This would yield a positive cashflow which would be offset by costs and obligations such as severance pay, demolition, site cleanup, etc. Also, one has to allow for a redeployment of some of this working capital to the extent Asarco merely transfers the same business elsewhere and consider the tax consequences of the write-off of Tacoma's net plant and equipment.

Table V-24 is a projected balance sheet for Tacoma as of December 31, 1977 when such a shutdown might occur. The balance sheet indicates our estimated allocation between Tacoma (inventory assets) and customers (metals accounts payables), and the net working capital position. Of the total projected current assets of about $46 million, projected current liabilities are estimated at $23 million; the current ratio is 2 to 1, and net working capital $23 million.

At the present time, we believe that Tacoma is carrying extraordinarily high inventories of copper, as is the entire industry. Thus, the $23 million net working capital is about $10-11 million in excess of that normally financed by Asarco. We believe the net working capital normally associated with Tacoma's on-going operations to be about $12 million (1978 dollars). This amount is the portion financed by Asarco above that amount financed by the shippers.

TABLE V-24

PROJECTED BALANCE SHEET ITEMS FOR TACOMA
AS OF DECEMBER 31, 1977
(in millions of dollars)

Current Assets		Current Liabilities	
Normal inventories of metals[a]	30	Metals Payables[b]	16
Accounts Receivable	6	Other Accounts Payable	2
Sub-Total - Normal Current Assets	36	Deferred Toll Revenues	5
Excess Inventories[c]	10		
Total Current Assets	46	Total Current Liabilities	23

Memo

(1) Net Working Capital = 13 (normal basis)

(2) Current Ratio = 2.0 (current basis)

		Debt and Equity Capital	55
Net Plant and Equipment	32		
Total Assets	78	Total Liabilities	78

Notes: a. Normal inventory pipeline is 40% of the metals (copper, gold and silver) value produced @ 100,000 tons copper per year, worth an estimated $200 million in 1977 prices. Tacoma assumed to finance 15%, the mines 25% of this 40%.

b. 100,000 short tons x 50% (custom) x 120 days payment cycle/year equals about 16,000 tons; 16,000 x 2000 lbs. short tons x $0.50 /lb. net equals $16 million.

c. At 80,000 tons/year, the approximate recent production rate, Tacoma has to finance 5000 tons additional pipeline requirements, or about $10 million.

We also estimate that at least six months worth of pre-tax earnings and a full year's depreciation charges would be available for cash flow in the year of shutdown.

In shutting down, our impression is that Tacoma would face severance pay plus on-going medical plan payments on behalf of workers, with a present value of approximately $3 million in 1978 dollars. We think that the extra recovery of precious metals accretions, plus average value of equipment, would be almost exactly offset by the probable cost of contract services for demolition at the plant site and additional costs of a caretaker crew.

The final major item would be future pension fund payments, to employees, a financial obligation of Asarco. The assumptions regarding pension plan liability are important since they can significantly affect the NPV. For example, this could be handled by the purchase of an annuity from an insurance company. We estimate the cost of this approach to be approximately $5-8 million in current dollars. The $5 million figure is obtained by taking the ratio of Tacoma employment to total Asarco employment times the reported actuarially computed value of vested pension benefits. The $8 million figure represents the prorated unfunded past service liability in Asarco's retirement plan. On the other hand, assuming Asarco guarantees the pension payments itself and funds them over 20 years (the same period over which the obligation is likely to be amortized for financial accounting purposes) there would be no lump sum purchase of an annutiy. Instead, it would be based on Asarco's discount rate, which is higher. Using $400,000/year as an estimate of average required payments, and discounting at 10% for 20 years, the present value would only be $3.4 million which is $1.6 to 4.6 million lower than the amount needed for the purchase of an annuity. The difference is even greater if higher discount rates are used.

For Table V-24, we assumed that the depreciated book value, less salvage value, would be roughly $26 million at the end of 1978. Suppose one were to use an even lower figure of roughly $20 million, and the 48% marginal tax rate, then assuming Asarco has taxable income to offset in 1978 and 1979, the write-off of the net Tacoma plant and equipment could produce a tax credit which would increase Asarco's cash flow in 1978 and/or 1979, with a present value on the order of nearly $10 million.

Thus, we estimate that the shutdown of Tacoma in 1978 would produce the following net present value (NPV) in millions of dollars:

NPV $\approx$ \$23 net working capital

	\$23	net working capital
+	3	cashflow from final operations
-	5 to 8	pension fund liability (could be lower)
-	8	present value for installation of matte and speiss treatment facilities
-	3	severance pay, etc.
+	10	tax credit from shutdown
	\$17-20	

Given the shutdown alternative, one can then calculate and compare how long Tacoma would have to operate "as is" with the base case after-tax cashflow of \$3.0 million/year (i.e., with no incremental pollution control), to exceed the net present value of shutting down in 1978--say roughly \$15-20 million. The results are:

	@ \$20 Million	@ \$15 Million
@ 10% discount rate,	11.5 years	7.3 years
@ 15% discount rate,	Forever	10.0 years

Of course, this should not be construed to suggest that shutdown is an attractive alternative in and of itself. Obviously, *ceteris paribus*, Asarco-Tacoma would lose the present value associated with an ongoing operation. It is only when it is recognized that Tacoma probably cannot expect to maintain the status quo that the shutdown calculation arises--then it is in the context of comparison with the alternative environmental control investment options which are available.

G. SENSITIVITY ANALYSIS

The economic impact analysis reported above was performed under a set of assumed base conditions. In this section, we report on an analysis of the sensitivity of the conclusions reached under base conditions to progressive relaxation of the hypothesized base conditions. Specifically, we examine here the sensitivity of the conclusions reached earlier to the following: (a) the hypothesis that Tacoma adopts a discriminatory monopolistic pricing behavior to maximize its revenues during the 1978-1995 period, (b) consideration of other environmental regulations and costs of compliance associated with them, (c) variability in the transportation costs and "distress" payments, (d) variability in estimates of capital expenditures for pollution control, and (e) alternative ways of time-phasing capital expenditures for pollution control.

The sensitivity of the conclusions reached under base conditions, as well as the sensitivity of those reached under the relaxation of the base conditions to still other variations in assumptions (e.g., lower production levels at Tacoma, higher "base" profits and cash-flow at Tacoma, etc.) are explored by inspection and/or deduction.

1. Sensitivity Analysis under the Hypothesis that Tacoma Adopts a Discriminatory Monopolistic Pricing Behavior during the Period 1978-1995

One set of sensitivity analyses can be performed under the hypothesis that Tacoma adopts a discriminatory monopolistic pricing strategy over the period 1978-1995. We have explained in some detail in Chapter IV how the relevant market in which Tacoma operates consists of participants who are interdependent, exhibiting characteristics of bilateral oligopoly. That is to say, we have here a situation where a few buyers (i.e., mines or suppliers of concentrate/scrap, buying smelting/refining services) confront a few sellers (i.e., Tacoma, Japanese smelters and the new Philippines smelter scheduled to start operations at the beginning of 1981, selling smelting/refining services). The concept of discriminatory monopolistic pricing strategy, in the context used here, can be described essentially as follows: what is the maximum smelting/refining toll charge Tacoma can exact from each mine or supplier of feedstocks in order to maximize its total revenues, over the period 1978-1995, taking into consideration expected (hypothesized) copper prices, each supplier's costs of production, Tacoma's potential competition in terms of the availability of smelting/refining services provided by others and their respective costs (including differential transportation costs). This helps define, under each hypothesized copper price, the degree of freedom available to, and the constraints operating upon, each one of Tacoma's suppliers. From this evolves an internally consistent set of conditions defining precisely how much in the way of smelting/refining charges Tacoma can hope to extract from each supplier over time, by pushing each supplier to the brink of closing down or switching to an alternative smelter/refiner. In short, under such a pricing strategy, Tacoma exercises whatever market power it possesses at any time to its own full advantage, both short-term and long-term, which includes charging the various suppliers at different (discriminatory) rates specifically tailored to exploit each supplier to the maximum.

a. Estimates of Tacoma's Expected Revenues under Discriminatory Monopolistic Pricing Strategy

For purposes of sensitivity analysis, we have computed total expected annual revenues, over the period 1978-1995, that Tacoma could theoretically attain at various assumed copper prices by adopting a discriminatory monopolistic pricing strategy. The results of this analysis are summarized in Table V-25. The detailed results, corresponding to various assumed copper price levels, are tabulated in Tables V-26 through V-29. The technical notes given at the end of these tables explain the rationale of the numerical estimates

TABLE V-25

SUMMARY: TOTAL EXPECTED ANNUAL REVENUES AT TACOMA, 1978-1995, FOR SENSITIVITY ANALYSIS UNDER DISCRIMINATORY MONOPOLISTIC PRICING AT VARIOUS ASSUMED COPPER PRICES
(millions of 1978 dollars)

Description (see text)	Total Expected Annual Revenues at Tacoma Copper Prices (¢/lb.; in 1978 prices)			
	80	85	90	100
Version A: Lepanto Drops Out After 1980				
1978 - 1980	65.63	68.79	71.94	78.25
1981 - 1995	56.34	56.34	56.34	56.34
Version B: Lepanto Stays After 1980				
1978 - 1980	58.18	61.11	64.26	70.57
1981 - 1995	59.18	59.18	59.18	59.18

Source: Refer to Tables V-26 to V-29.

TABLE V-26

EXPECTED MAXIMUM ANNUAL REVENUES AT ASARCO-TACOMA, 1978-1995, FOR SENSITIVITY ANALYSIS
(millions of 1978 dollars)

Key Assumptions:
(1) Domestic/LME copper price at 80.0¢/lb., 1978-1995
(2) Asarco-Tacoma exercises market power and adopts monopolistic discriminatory pricing strategy
(3) Lepanto is pushed to the limit in 1978-1980 and, for reasons explained in the text, discontinues shipments in 1981 but is replaced by suppliers of domestic clean concentrates (Version A); or Lepanto is priced by Asarco-Tacoma to retain it as a long-term client/source (Version B)

Revenues From / Years	Duval and other Southwestern mines with clean concentrates[a] 1978-1980: 93.0×10^6 lbs./yr. 1981-1995: 131.4×10^6 lbs./yr.	Lepanto 1978-1980: 38.4×10^6 lbs./yr. 1980-1995: 0.0 lbs./yr.	Northern Peru 11.52×10^6 lbs./yr.	East Helena 13.2×10^6 lbs./yr.	Precipitates and scrap sources[c] 22.0×10^6 lbs./yr.	Expected annual byproduct revenues[d]	TOTAL ANNUAL REVENUES
80¢/lb.; Version A							
1978-1980	25.575	16.128[b]	4.838[b]	5.540[b]	9.944	3.600	65.625
1981-1995	36.135[i]	0.0	3.802[f]	4.356[f]	9.944	2.100[e]	56.337
80¢/lb.; Version B							
1978-1980	25.575	8.678[g]	4.838[b]	5.540[b]	9.944	3.600	58.175
1981-1995	25.575	11.904[h]	3.802[f]	4.356[f]	9.944	3.600	59.181

Note: Footnotes are given at the end of the tables.

TABLE V-27

EXPECTED MAXIMUM ANNUAL REVENUES AT ASARCO-TACOMA, 1978-1995, FOR SENSITIVITY ANALYSIS
(millions of 1978 dollars)

Key Assumptions: (1) Domestic/LME copper price at 85.0¢/lb., 1978-1995
(2) Asarco-Tacoma exercises market power and adopts monopolistic discriminatory pricing strategy
(3) Lepanto is pushed to the limit in 1978-1980 and, for reasons explained in the text, discontinues shipments in 1981 but is replaced by suppliers of domestic clean concentrates (Version A); or Lepanto is priced by Asarco-Tacoma to retain it as a long-term client/source (Version B)

Revenues From / Years	Duval and other Southwestern mines with clean concentrates[a] 1978-1980: 93.0 x 10^6 lbs./yr. 1981-1995: 131.4 x 10^6 lbs./yr.	Lepanto 1978-1980: 38.4 x 10^6 lbs./yr. 1980-1995: 0.0 lbs./yr.	Northern Peru 11.52 x 10^6 lbs./yr.	East Helena 13.2 x 10^6 lbs./yr.	Precipitates and scrap sources[c] 22.0 x 10^6 lbs./yr.	Expected annual byproduct revenues[d]	TOTAL ANNUAL REVENUES
85¢/lb.; Version A							
1978-1980	25.575	18.048[b]	5.414[b]	6.204[b]	9.944	3.600	68.785
1981-1995	36.135[i]	0.0	3.802[f]	4.356[f]	9.944	2.100[e]	56.337
85¢/lb.; Version B							
1978-1980	25.575	10.368[g]	5.414[b]	6.204[b]	9.944	3.600	61.105
1981-1995	25.575	11.904[h]	3.802[f]	4.356[f]	9.944	3.600	59.181

Note: Footnotes are given at the end of the tables.

TABLE V-28

EXPECTED MAXIMUM ANNUAL REVENUES AT ASARCO-TACOMA, 1978-1995, FOR SENSITIVITY ANALYSIS
(millions of 1978 dollars)

Key Assumptions:
(1) Domestic/LME copper price at 90.0¢/lb., 1978-1995
(2) Asarco-Tacoma exercises market power and adopts monopolistic discriminatory pricing strategy
(3) Lepanto is pushed to the limit in 1978-1980 and, for reasons explained in the text, discontinues shipments in 1981 but is replaced by suppliers of domestic clean concentrates (Version A); or Lepanto is priced by Asarco-Tacoma to retain it as a long-term client/source (Version B)

Revenues From / Years	Duval and other Southwestern mines with clean concentrates[a] 1978-1980: 93.0 x 10^6 lbs./yr. 1981-1995: 131.4 x 10^6 lbs./yr.	Lepanto 1978-1980: 38.4 x 10^6 lbs./yr. 1980-1995: 0.0 lbs./yr.	Northern Peru 11.52 x 10^6 lbs./yr.	East Helena 13.2 x 10^6 lbs./yr.	Precipitates and scrap sources[c] 22.0 x 10^6 lbs./yr.	Expected annual byproduct revenues[d]	TOTAL ANNUAL REVENUES
90¢/lb.;Version A							
1978-1980	25.575	19.968[b]	5.990[b]	6.864[b]	9.944	3.600	71.941
1981-1995	36.135[i]	0.0	3.802[f]	4.356[f]	9.944	2.100[e]	56.337
90¢/lb.;Version B							
1978-1980	25.575	12.288[g]	5.990[b]	6.864[b]	9.944	3.600	64.261
1981-1995	25.575	11.904[h]	3.802[f]	4.356[f]	9.944	3.600	59.181

Note: Footnotes are given at the end of the tables.

TABLE V-29

EXPECTED MAXIMUM ANNUAL REVENUES AT ASARCO-TACOMA, 1978-1995, FOR SENSITIVITY ANALYSIS
(millions of 1978 dollars)

Key Assumptions: (1) Domestic/LME copper price at 100.0¢/lb., 1978-1995
(2) Asarco-Tacoma exercises market power and adopts monopolistic discriminatory pricing strategy
(3) Lepanto is pushed to the limit in 1978-1980 and, for reasons explained in the text, discontinues shipments in 1981 but is replaced by suppliers of domestic clean concentrates (Version A); or Lepanto is priced by Asarco-Tacoma to retain it as a long-term client/source (Version B)

Revenues From / Years	Duval and other Southwestern mines with clean concentrates[a] 1978-1980: 93.0×10^6 lbs./yr. 1981-1995: 131.4×10^6 lbs./yr.	Lepanto 1978-1980: 38.4×10^6 lbs./yr. 1980-1995: 0.0 lbs./yr.	Northern Peru 11.52×10^6 lbs./yr.	East Helena 13.2×10^6 lbs./yr.	Precipitates and scrap sources[c] 22.0×10^6 lbs./yr.	Expected annual byproduct revenues[d]	TOTAL ANNUAL REVENUES
100¢/lb;Version A							
1978-1980	25.575	23.808[b]	7.142[b]	8.184[b]	9.944	3.600	78.253
1981-1995	36.135[i]	0.0	3.802[f]	4.356[f]	9.944	2.100[e]	56.337
100¢/lb;Version B							
1978-1980	25.575	16.128[g]	7.142[b]	8.184[b]	9.944	3.600	70.573
1981-1995	25.575	11.904[h]	3.802[f]	4.356[f]	9.944	3.600	59.181

Note: Footnotes are given at the end of the table.

NOTES ACCOMPANYING TABLES V-26 THROUGH V-29

a. At 27.5¢/lb., which defines the estimated "trigger" point for Duval and other Southwestern suppliers of clean concentrates, derived as follows

$$p^T + c_1 < p^J + c_2 + d$$

where (¢/lb., in 1978 prices)

p^T: smelting/refining charge at Tacoma (cents per pound of copper content),

c_1: weighted average transportation cost from Battle Mountain and the Southwest (e.g., Sierrita) to Tacoma, estimated at 3.5¢/lb.,

c_2: weighted average transportation cost to Japan from Battle Mountain and the Southwest, estimated at about 5¢/lb.;

d : "distress payment" to Japanese smelters, for accommodating foreign concentrates, estimated at about 4¢/lb.,

p^J: the average smelting/refining change at Japanese smelters, estimated at 22¢/lb.,

then,

$$p^T + 3.5¢/lb. \lesssim 2.20¢/lb. + 5.0¢/lb + 4.0¢/lb.$$

$$p^T \leq 22.0 + 5.0 + 4.0 - 3.5$$

$$p^T \leq 27.5¢/lb.$$

p^T must be less than or equal to 27.5¢/lb as a condition for Duval and other southwestern suppliers of clean concentrates not to shift to Japan.

b. Estimated from the following conditions:

$$p^{cu} - (p_i^T + c_i) \geq c_i^{avc}$$

where (¢/lb., in constant 1978 prices):

p^{cu} : price of copper,

p_i^T : smelting/refining charge at Tacoma for mine/mill i (i = 1, ..., m);

c_i : estimated transportation cost from mine/mill i (i = 1, ..., m) to Tacoma;

c_i^{avc}: estimated average (unit) operating and maintenance costs (i.e., average variable costs) at mine/mill i (i = 1, ..., m), where operating and maintenance costs are defined to include estimated required interest payments.

This inequality says that at a given copper price, Tacoma will charge the mine as high as possible but just short of causing the mine to shut down (i.e., the mine is barely able to cover its variable costs, including estimated required interest payments).

Using our estimates of c_i and c_i^{avc}, we can solve for p_i^T for the various mines as follows under given levels of p^{cu} (for t = 1978, 1979 and 1980);

$$p^T \lesssim p_i^{cu} - c_i - c_i^{avc}.$$

For Lepanto and Northern Peru, estimates of c_i and c_i^{avc} are as follows:

c_i = 3.0¢/lb. (in 1978 prices)

c_i^{avc} = 35.0¢/lb. (in 1978 prices).

Then, estimates of p_i^T (maximum charges that can be exacted by Tacoma) under various copper price levels can be derived as follows:

At p^{cu} (¢/lb.; in 1978 prices)	p_i^T is (¢/lb.; in 1978 prices)
80.0	42.0
85.0	47.0
90.0	52.0
100.0	62.0

These results for Lepanto and Northern Peru are also assumed to hold for East Helena (p^T is the same for three mines).

c. Estimated at 22.6¢/lb., since the demand schedule of the precipitate and scrap suppliers for Tacoma's services is assumed perfectly elastic (i.e., Tacoma will be unable to charge them more than 22.6¢/lb., as they can readily switch to alternative processing plants and pay no more than an estimated 22.6¢/lb.)

d. Same as expected annual byproduct revenues assumed under "base" conditions, described earlier.

e. The drop of $1.5 million/year in expected byproduct revenues is due to Lepanto's falling out in 1981. Under "base" conditions, Lepanto is estimated to account for about $1.5 million of Tacoma's roughly $2.7 million per year revenues from arsenic sales.

f. With the potential (planned) availability of a new ocean-front smelter in the Philippines as of the beginning of 1981, with enough extra capacity to accommodate both Northern Peru and (in principle) East Helena, we have estimated the maximum charge that Tacoma could exact (in the case of Northern Peru) from the following inequality which defines Northern Peru's "trigger" point, effective after 1980.

$$p^T + c_3 \lesssim p^P + c_4$$

where (¢/lb., in 1978 prices):

p^T : smelting/refining charge at Tacoma;

c_3 : transportation cost from Northern Peru (Quiruvilca Mine) to Tacoma (estimated at 3¢/lb.);

p^P : smelting/refining charge at the new Philippines smelter (estimated as 33.0¢/lb);

c_4 : transportation cost from Northern Peru (Quiruvilca Mine) to the new ocean-front Philippines smelter (estimated as 3.0¢/lb)

Since c_3 and c_4 fall out (i.e., $c_3 = c_4$), we have $p^T < p^P$ (i.e., p^T cannot exceed 33.0¢/lb.). We have assumed, to simplify matters, that this boundary condition also holds for East Helena. For these revenue calculations p^T is hence set at 33.0¢/lb.

g. Derived from the following inequality:

$$p^T \leq p^{cu} - c_5 - c^{atc}$$

where (¢/lb.; in 1978 prices):

p^T : smelting/refining charge at Tacoma;

p^{cu} : price of copper;

c_5 : transportation cost from Lepanto to Tacoma (estimated as 3.0¢/lb.);

c^{atc} : Lepanto's average total cost (unit cost), which includes both fixed and variable costs, where fixed costs are defined to include a "normal" rate of return on invested capital. It is estimated as 55.0¢/lb.

p^T can thus be computed for various levelized copper prices as follows:

At p^{cu} (¢/lbs.; in 1978 prices)	p^T is (¢/lb.; in 1978 prices)
80.0	22.0 (not used; see note below)
85.0	27.0
90.0	32.0
100.0	42.0

At p^{cu} = 80¢/lb., we have not used the resulting p^T = 22.0¢/lb. but rather chose to price Lepanto at the "base" smelting/refining charge of p^T = 22.6¢/lb.

h. For the period after 1980, the maximum amount Tacoma can charge Lepanto is calculated from the following set of conditions:

$$p^T + c_5 < p^P + c_6$$

where (¢/lb.; in 1978 prices)

p^T : smelting/refining charge at Tacoma;

c_5 : transportation cost from Lepanto to Tacoma (estimated as 3.0¢/lb.);

p^P : smelting/refining charge at the new Philippines smelter (estimated as 33.0¢/lb.);

c_6 : transportation cost from Lepanto to the new Philippines smelter (estimated as 1.0¢/lb.).

We can hence solve for p^T as follows:

p^T + 3.0¢/lb. $\leq$ 33.0¢/lbs. + 1.0¢/lb.

$p^T \leq 33.0 + 1.0 - 3.0$

$p^T \leq$ 31.0¢/lb.

What next remains to be demonstrated is that at p^T = 31.0¢/lb., both necessary and sufficient conditions will be met by Lepanto to remain open. It can be seen, by inspection, that the mining/milling cost to Lepanto, plus the transportation cost, is 34.0¢/lb. Then, Lepanto's realized concentrate netback is as follows under different copper prices:

Copper price (p^{cu}) (¢/lb.)	Lepanto netback on concentrate (¢/lb.)
80.0	46.0
85.0	51.0
90.0	56.0
100.0	66.0

Given our estimate of Lepanto's costs (i.e., average variable costs of 35.0¢/lb., including estimated required interest payments; and, average total cost--or unit cost--of 55.0¢/lb., which includes a "normal" rate of return on invested capital), it would appear that, at copper prices of 80.0¢/lb. and 85¢/lb., Lepanto may stay open with difficulty and/or considerable reluctance on what would seem to be a long-run basis. The revenue stream resulting for Tacoma from this analysis would hence look highly favorable under any of the control options studied.

The analysis presented above is favorably inclined towards Tacoma for a related yet still another reason. Lepanto, anticipating such an outcome after 1980 under a levelized copper price of 80.0¢/lb. (or 85.0¢/lb.), might decide, after all, not to expand its capacity over the period 1978-1980 in order to feed both Tacoma and the new smelter. The analysis is hence strained, in favor of Tacoma staying open under the various control options, by hypothetically imputing an investment behavior to Lepanto, under a perceived long-run price of copper in the 80.0 - 85¢/lb. range, which in reality may not come to pass.

i. Reflects the assumption that if, under this scenario (Version A), Lepanto falls out after 1980, it will be replaced by domestic clean concentrates.

presented in these tables.

For this analysis, we have hypothesized a future "state of the world" where domestic smelter capacity growth is effectively constrained through 1983 at the earliest, but where sufficient Japanese smelter capacity will continue to be available to absorb some "overflow" U. S. concentrates (e.g., Duval and other suppliers of domestic clean concentrates), and where a new Philippines smelter potentially competing with Tacoma, especially with respect to "dirty" concentrates, is scheduled to commence operations at the beginning of 1981.

Our revenue calculations under the hypothesized "state of the world" and discriminatory monopolistic pricing behavior on the part of Tacoma consider two variations: (1) Lepanto is pushed to the limit during the period 1978-1980 and, for reasons indicated below, discontinues shipments to Tacoma after 1980 (Version A)[1], and (2) Lepanto is priced by Tacoma to retain it as a long-term client/source, even after Lepanto has its own home smelter starting in 1981 (Version B). These two different ways of considering the Lepanto-Tacoma relationship, which result in two different expected revenue streams for Tacoma over the period 1978-1995 under each hypothesized copper price level, arise basically from the following set of factors.

As we interpret the situation, Lepanto is officially obligated to have a substantial quantity of its concentrates processed at the new Philippines smelter scheduled to start operations at the beginning of 1981. This means Lepanto faces the following decision before 1981: (a) expand concentrate production capacity not only to supply Tacoma at the base rate (i.e., 19,200 short tons/year), but also to supply the new home smelter after 1980; or (b) do not expand mine capacity; discontinue shipments to Tacoma after 1980 in order to feed the new home smelter. Which course Lepanto might take would depend, in substantial measure, on Tacoma's pricing behavior vis-à-vis Lepanto. If Tacoma prices Lepanto as a short-run profit-maximizing monopolist over the period 1978-1980, Tacoma would attempt to extract the maximum toll from Lepanto under a given copper price level which would result in Lepanto barely staying open let alone considering any expansion program. In other words, under such a situation, Lepanto would be barely covering the out-of-pocket costs (i.e., operating and maintenance expenses, including required interest payments). Thus, not being in a profitable position to expand its capacity, Lepanto would be forced to divert all its concentrate supply to the new home smelter; since Lepanto is officially committed to supply the new smelter, and discount pricing by Tacoma to keep any part of Lepanto's feed after 1980 would not alter this basic conclusion.

---

1 It is assumed, in this case, that Lepanto is replaced by domestic suppliers of clean concentrates.

For Tacoma, there is an alternative to the short-run monopolistic pricing of Lepanto over the 1978-1980 period. Tacoma will most likely conclude that if its objective is to retain Lepanto as a long-term client/source, then the pricing strategy consistent with this objective would be as follows: Tacoma would price Lepanto over the 1978-1980 period in such a way that Lepanto will in fact be able to expand its capacity and, beyond 1980, charge Lepanto no higher than it would cost Lepanto at the new smelter, taking into account transportation cost differentials.

Thus, under the conditions described above, discriminatory monopolistic pricing behavior may be hypothesized for Tacoma for a sensitivity analysis. While such behavior is theoretically plausible, such a pricing strategy implies or directly involves the following:

- It represents a sharp reversal of how smelting/refining services have traditionally been priced and performed in the past in this country and abroad among nonferrous metals companies which typically deal with each other, in terms of joint investments or in terms of buyer-seller relationships (as here) on the basis of long-run considerations which also typically have been devoid of deliberate or manipulative profit-maximizing behavior such as basically hypothesized here for Tacoma.

- It would require, as far as we can discern, that Tacoma (or Asarco, Inc.) invoke the <u>force majeure</u> clause in its existing smelting/refining contracts. Without passing on the legality of such action on the part of Tacoma (or Asarco, Inc.), it must be noted that this might be considered by Tacoma's suppliers--some of which (e.g., Duval) have a wider set of relationships with Asarco, Inc., which transcend the limited set of relationships concerning Tacoma specifically--as being tantamount to abrogation of contract.

- It represents a mode of behavior on the part of Tacoma (or Asarco, Inc.), towards the various suppliers, quite different from that displayed in a similar but far less serious recent situation, when one supplier (i.e., Cyprus Mines) dropped out and the remaining ones (e.g., Duval, Lepanto) "complained." Historical analogies are hazardous at best, but it may be instructive to review, briefly, this recent, similar situation involving Tacoma with relatively minor dimensions of cost pass-on but nevertheless with potentially instructive consequences.

  As indicated earlier in this chapter, starting in 1970 Asarco instituted a pollution control surcharge of 1¢/lb. when copper prices remained less than or equal to 50¢/lb. and 1.5¢/lb. when copper prices rose above 50¢/lb. This arrangement applied to <u>all</u> suppliers of concentrates for toll smelting to the three Asarco copper smelters (Tacoma, Hayden, El Paso). This surcharge, instituted to help finance pollution control costs at the three smelters, was phased out at the end of 1975.

Two points should be noted in this connection. First, Asarco did not invoke force majeure; the surcharge was instituted after informal negotiations with the suppliers, when Asarco's position was one of "sharing" the pollution control cost burden with the suppliers. Of course, in the present instance, neither Asarco (or Tacoma) nor such suppliers as Duval may be as inclined to seek a cooperative arrangement when the pollution control cost burden might be far greater. This basically supports the main points made earlier.

Second, the decision of Cyprus Mines to discontinue supplying Tacoma when faced with a surcharge of no more than 1.5¢/lb., may also serve to illustrate a point. Considerations of production costs, as well as the availability of alternative smelters (i.e., Phelps Dodge's) at lower cost must have all played a role. At the same time, we should like to underscore, without proof, the point that real world decisions or reactions may at times bear little relationship to those expected from various participants on the basis of rational behavior consistent with economic principles, as posited here. In other words, actual decisions/reactions in response to Tacoma's hypothesized discriminatory monopolistic pricing behavior might end up being far more "jerky" or discontinuous than indicated by theory, such that various participants may take decisions (e.g., Duval switching to a Japanese smelter) even before the limits suggested by theory (e.g., Duval's "trigger" point of 27.5¢/lb.) are reached. In general, then, the behavioral conditions hypothesized here, under a discriminatory monopolistic pricing strategy on the part of Tacoma, circumscribe the "upper bound" on revenues that Tacoma can expect to attain under the various assumed copper price levels.

b. Results Under Discriminatory Monopolistic Pricing

There are numerous computational combinations for estimating the revenue streams for Tacoma at different assumed copper price levels under the hypothesis that it will adopt discriminatory monopolistic pricing over the period 1978-1995. These combinations involve six control options, four assumed copper price levels, two different sets of revenue streams under each assumed copper price level (i.e., Version A, with Lepanto falling out after 1980 and Version B, with Lepanto staying after 1980), at two discount rates (i.e., 10% and 15%), and considering Tacoma in two different or alternative ways (i.e., as part of the parent company and on a stand-alone basis).

Typically, expected annual revenues for the earlier years, which are important in cash-flow analysis, are higher under Version A than under Version B, under each assumed copper price level. We hence performed a series of sensitivity analyses by using Version A revenue streams for the following reasons:

- Under each assumed copper price level, Version A provides the upper bound front-end revenue streams which provide the most generous revenue conditions for any of the control options.

- This allows us to explore the "threshold" conditions for any of the control options to be considered viable. That is, if a given control option appeared viable, for example, at an assumed copper price level of 85¢/lb., it would be clear that it would also be viable at higher copper prices, under the same set of pricing-behavioral assumptions. The conclusions reached, then, would also generally hold under Version B revenues. Conversely, if a given control option failed to be considered viable under any of the copper price assumptions, then this would indicate certain failure under Version B revenues.

In similar vein, the consideration of Tacoma as part of a parent company (i.e., as part of Asarco, Inc.) rather than on a stand-alone basis, would cast the outcome in a more favorable light if the resulting net present value under a given control option is negative, since the losses and/or income tax credits at Tacoma could then be used by the parent company as offsets against its corporate income tax liability in its consolidated income tax return.

The sensitivity analysis results are tabulated in Table V-30. This analysis leads us to the following conclusions:

- Control Option 4.1B (Minimum Control, No OSHA) is clearly viable at 80¢/lb. copper price, under the hypothesized conditions. Control Option 3.1B (Intermediate; Delay, no OSHA), however is barely viable at 80¢/lb. copper price.

- Control Option 4.2B (Minimum Control, with OSHA) appears viable under 85¢/lb. copper price, at a discount rate of 10%, but is at best ambiguously viable at a discount rate of 15%. At long-term equilibrium copper price levels above 85¢/lb., this option would be more clearly and unambiguously viable.

- Control Option 3.2B (Intermediate; Delay; with OSHA) becomes ambiguously viable at 100¢/lb. copper price, at 10%, but fails to be considered viable at 15%.

- Control Option 1.1B (Maximum Control, no OSHA) appears barely viable at 90¢/lb., at 10%, but fails, by a small margin, to be considered viable at 15%.

- Control Option 1.2B (Maximum Control, with OSHA), with negative net present value even at 100¢/lb. copper price, is clearly not viable.

TABLE V-30

SENSITIVITY ANALYSIS RESULTS UNDER THE HYPOTHESIS THAT TACOMA ADOPTS A DISCRIMINATORY MONOPOLISTIC PRICING BEHAVIOR DURING THE PERIOD 1978-1995 UNDER ALTERNATIVE ASSUMED COPPER PRICE LEVELS[a,b]

TACOMA IS CONSIDERED AS PART OF THE PARENT COMPANY, ASARCO, INC.

(in millions of 1978 dollars)

Options Considered	Net Present Value (NPV) of After-Tax Cash Flow, 1978-1995, at different assumed price levels and discount rates							
	80¢/lb.		85¢/lb.		90¢/lb.		100¢/lb.	
	@10%	@15%	@10%	@15%	@10%	@15%	@10%	@15%
Control Option 4.1B-Minimum	+49	+38						
Control, No OSHA			Feasible					
Control Option 4.2B-Minimum	+19	+14	+23	+18		Feasible		
Control, with OSHA		marginally feasible						
Control Option 3.1B-Intermediate;	+22	+18				Feasible		
Delay; no OSHA	marginally feasible							
Control Option 3.2B-Intermediate;		not feasible			+2	lower	+18 max.	+14 max
Delay; with OSHA							marginally feasible	
Control Option 1.1B-Maximum,	+10	+12			+18 max.	+16 max.		
No OSHA		not feasible				marginally feasible		
Control Option 1.2B-Maximum,					-14	-11		
with OSHA							<-1	<-1
		not feasible						
TACOMA SHUTDOWN	+17 to +20		+17 to +20		+17 to +20		+17 to +20	

Notes: a. For purposes of the sensitivity analysis reported here, we have used the expected revenue estimates under Version A (i.e., Lepanto falls out after 1980) which yields higher revenues in earlier years than are obtained under Version B (i.e., Lepanto stays after 1980).

b. The results presented in this table have been obtained by performing the same computations reported in connection with Option 4.2B presented earlier as an example. It should be noted that whereas the results given for Option 4.2B contain accelerated depreciation the results given for all other options involve the use of straight-line depreciation. It will be recalled from a discussion given earlier that the use of one or the other method of estimating depreciation has little effect on the results.

c. Assumes that tax credits associated with ITC and/or losses at Tacoma will be utilized by the parent company (Asarco, Inc.) as offsets against its corporate income tax liability in its consolidated income tax return.

d. The net present value figures shown here represent the most optimistic outcomes (i.e., if the net present value figures are computed more fully, beyond the certain number of years considered here, the results would be even more negative).

2. Other Environmental Regulations and Associated Compliance Costs

The baseline analysis in Section E specifically takes into account the costs for meeting the proposed OSHA standard for Inorganic Arsenic of 0.004 $mgAs/m^3$. This standard has yet to be promulgated and a possibility remains that another standard requiring less expenditures could be promulgated instead or that the expenditures could be stretched out over a period of time much longer than the six year period assumed by us. While either of these two possible variations on our earlier "base" assumptions on both costs and time-phasing concerning OSHA regulations would lead to less serious economic impacts, it is difficult to assess the probability that either of these two alternative cases might in fact occur, before their relative effect on the impact results can be determined.

At any rate, while the lower-cost and longer time-phasing considerations, or both taken together, might lead to lower economic impacts, it should also be noted that Tacoma faces other possible regulations and compliance costs, such as OSHA in-plant lead and SO_2 standards, EPA ambient lead and arsenic standards and so on. These potential future regulatory costs and related uncertainty could affect Asarco's perception of risk and of the future viability of Tacoma. This, in turn, could affect the perceptions of the viability of additional SO_2 control.

3. Transportation Costs and "Distress" Payment

The various "trigger prices" used in our analysis can be reestimated on the basis of an alternative (higher) set of transportation costs presented in Appendix J and a different amount for "distress payment".

a. "Distress Payment" of 4¢/lb.

- Duval and other Southwestern suppliers of clean concentrates:

$$p^T + c_1 \leq p^J + c_2 + d$$

$$p^T + 5.6 \leq 22 + 4 + 4$$

$$p^T \leq 24.4¢/lb.$$

(baseline analysis value = 27.5¢/lb.)

- Northern Peru after 1980

$$p^T + c_3 \lesssim p^P + c_4$$

$$p^T + 4 \lesssim 33 + 4$$

$$p^T \lesssim 33¢/lb.$$

(baseline analysis value = 33¢/lb.)

- Lepanto after 1980

$$p^T + c_5 \lesssim p^T + c_6$$

$$p^T + 4 \lesssim 33 + 1.5$$

$$p^T \lesssim 30.5¢/lb.$$

(baseline analysis value = 31¢/lb.)

It can be seen by comparison with the baseline analysis values that the higher transportation costs result overall in lower revenues to Tacoma. Thus the cashflows and resultant NPV's would be lower than under the baseline analysis. These same conclusions apply to findings under Tacoma's hypothesized discriminatory monopolistic pricing behavior.

b. Other "Distress Payments"

Since the switching of Duval and other Southwestern mines to Japan would be on a continuing basis, one can hypothesize that the distress payment could be negotiated to a lower value, say 3¢/lb. Under these conditions, the "trigger" point for these mines would be 26.5¢/lb. under baseline transportation costs and 23.4¢/lb. under the higher costs. Alternatively, under the higher transportation cost scenario, the distress payment would have to be as high as 7¢/lb. in order for Tacoma's revenues from this source (i.e., clean concentrates) equal to those considered for baseline analysis.

4. Alternate Production Costs and Cash Flows

Several alternate production costs and alternate cash flow scenarios have been hypothesized for sensitivity analysis.

a. Production of 95,000 Tons/Year

Table IV-4 presented our estimates for this option. The pre-tax profit is reduced from $3.3 million to $2.1 million. Thus this would decrease NPV of the "baseline" options by $6 million at a 10% discount rate and by $4 million at a 15% discount rate. The results are less favorable than under the baseline analysis.

b. Decrease in Variable Costs

We have arbitrarily increased pre-tax profit to 10% of sales (i.e., to $4.9 million); we further assumed that this increase is achieved via a decrease in variable cost by $1.6 million.

This would increase after-tax cash flow by $0.8 million/year compared to the baseline analysis, and increase the NPV by +$7 million at a 10% discount rate and by +$5 million at a 15% discount rate. This does not alter the conclusions.

c. Different Depreciation Rates

We used 11-year straight-line depreciation for all pollution control options studied; and, additionally, we examined Option 4.2B in detail using accelerated depreciation. The use of these schedules is consistent with our understanding of Asarco's policy with regard to the ADR lives approved by IRS for nonferrous metals smelting and refining equipment.

A longer depreciation schedule would reduce the NPV of an option by the present value of the $0.48 tax savings foregone, per dollar of incremental depreciation.

The use of accelerated instead of straight-line depreciation added less than $2 million to the NPV's calculated for Option 4.2B. This difference is not large enough to affect the characterization of the feasibility space. Similar results would be obtained with respect to the other options studied.

d. Different Baseline Depreciation and Cash Flow Assumptions

Our methodology assumes baseline depreciation (i.e., in the absence of incremental control) normalized to an equilibrium in which the depreciation charge is exactly offset by ongoing replacement investment requirements. We estimated depreciation (and replacement investment) under the baseline conditions as $1.2 million/year. This resulted in an after-tax cash flow net of replacement requirements of $1.7 million/year. If we had assumed a higher depreciation rate of $2 million/year and an ongoing replacement investment rate of $2 million/year, the net after-tax cash flow would have been $1.3 million/year or $0.4 million/year less than under our baseline analysis. The effect of such a difference on the net present value figures is -$3.3 million at a 10% discount rate and -$2.5 million at a 15% discount rate. While the results are less favorable than under the baseline, the conclusions are not sensitive to differences of such magnitude.

Alternatively, if we had assumed a higher depreciation rate of \$2 million/year and an ongoing replacement investment rate of \$1.2 million/year, the net after-tax cash flow (net of replacement investment) would have been \$2.1 million/year or \$0.4 million/year higher than under the baseline analysis. The effect of such a difference on the net present value figures is +\$3.3 million at a discount rate of 10% and +\$2.5 million at a discount rate of 15%.

e. Historical Level of Cash Flow at Tacoma

Since pre-tax profit is the difference between two relatively large numbers--revenues and costs--its magnitude is sensitive to errors in estimation of either revenues or costs or both. An independent check on the validity of the profit and cash flow presented in Table IV-4 and used for the baseline analysis is a comparison with Tacoma's historical performance.

Asarco's December 5, 1975 Application for Variance to PSAPCA (supplied to us by EPA Region X) shows Tacoma's earnings over the period 1965-1974. The average pre-tax earnings for these 10 years were \$1.85 million/year and gross earnings were \$3.34 million/year. The average pre-tax earnings of \$1.85 million/year (in current dollars), after adjustment for inflation (i.e., expressed in 1978 dollars) is below the assumed baseline pre-tax earnings of \$3.3 million/year (in 1978 dollars). This suggests that the projected profit (and cash flow) under baseline conditions is on the high side compared to the historical performance.

In general, any combination of circumstances or errors resulting in a baseline after-tax cash flow difference of \$1 million per year would affect the NPV calculations by \$8 million at a 10% discount rate and \$6 million at a 15% rate. Since the difference between the NPV for Option 4.2B (minimum SO_2 control, with OSHA) under baseline analysis and the NPV associated with the shutdown Option is about \$40 million, baseline cash flow would have to increase by \$5 million/year at a 10% discount rate and by over \$6 million/year at a 15% discount rate before Option 4.2B becomes unambiguously feasible[1].

---

[1] This condition is approximately attained at 90¢/lb copper price level if Tacoma adopts a hypothesized discriminatory pricing behavior.

5. Capital Investment

Estimates of pollution control capital investment can vary significantly depending on the skills of the estimators, the degree of detail employed for the estimate (e.g., estimates based on preliminary layouts versus those based on detailed construction drawings) and the purpose of the estimate (e.g., an estimate prepared for a "paper" study versus that prepared for a fixed price construction bid). Thus it is important to examine the sensitivity of the findings to changes in capital investment. A range of +25% and -5% may typically be expected for projects of this type as noted earlier in Section C.

We examine below Option 4.2 (minimum SO_2 control, with OSHA) under base capital costs (Option 4.2B) and reduced capital costs (Option 4.2C) to see whether the findings change when the capital investment is reduced. The difference between the after-tax cash flows under these two control cost variants is the difference between the capital investment levels. Therefore, the net present value of this difference can be estimated separately. At a 10% discount rate, the NPV is $1.8 million and at a 15% discount rate, the NPV is $1.7 million. Thus, on a "with parent" and "stand alone" basis, respectively, the overall net present value for Option 4.2C is -$24.2 to -$38.2 million at a 10% discount rate and -$19.3 to -$29.3 million at a 15% discount rate. The observed differences from findings under base conditions are not significant enough to change the conclusions already reported for Option 4.2B or for any of the other higher cost options.

6. Time Phasing

The time phasing of the pollution control capital expenditures presented in Section C above was based on professional judgment. It can be argued that the same expenditures spread over a much longer time-period would show a less adverse impact, all else equal. While this argument is theoretically correct, all else does not remain "equal" when significant capital expenditures are stretched out over many years. A stretch-out of this type at Tacoma would increase the time-period over which the construction activity would interfere with production, thus resulting in higher costs of production. Moreover, construction projects of this type involve efficiency considerations in terms of scheduling, which would require, in this case, a project duration of 2-4 years for the efficient functioning of the construction team. A stretchout would introduce significant inefficiencies and increase total cost. Finally, the stretchout of a project into the distant future increases risk and uncertainty. This, in turn, requires the use of a higher discount rate to adjust for increased risk. The higher discount factor would tend to reduce any apparent benefits arising from such a stretchout.

7. Summary of Sensitivity Analysis Results

Table V-31 summarizes the results of the sensitivity analysis. Of all the factors considered, it can be seen that only two affect the conclusions derived under baseline conditions. These are persistently high copper prices starting in 1978 and Asarco's willingness (based on a perception that these price levels are persistent) to take advantage of this situation through discriminatory monopolistic pricing behavior.

H. OTHER ISSUES

1. A New Smelter in the Northwest

Since there might be a need for incremental smelter capacity in the U. S. over the impact analysis period of 1978-1995, it is relevant to examine whether a new smelter might be built in the Northwest. Such a new smelter could be based on conventional technology (such as reverb smelting) or new technology (such as electric or flash smelting) and could treat impure or only clean concentrates.

If such a smelter were based on impure concentrates, it would preferably be located on tidewater to receive imported concentrates. The New Source Performance Standards would permit the use of either reverb smelting or electric furnace smelting using double absorption acid plants for SO_2 control on strong streams. Weak streams produced by sources such as reverbs would not require permanent emission control, however, NAAQS would have to be maintained. Thus, one might argue that if Tacoma as a processor of impure concentrates were located in an area where it were not subject to the State of Washington/PSAPCA regulations, its current level of SO_2 control is equivalent to the NSPS requirement for the control of strong streams. If the Northwest continues to have relatively low cost electricity compared to the cost of fossil fuels, an electric smelter could be considered as an alternative for treating impure concentrates. This option has already been examined as Option 1.2B.

The other alternative is a smelter based on clean concentrates. Under the assumption of lower relative cost of electricity, an electric furnace smelter might be a preferred choice. Such a smelter would not necessarily require a tidewater location, since, based on current trends in mine production of copper, the concentrates for such a smelter would probably come from Arizona. Thus, as a first approximation, an electric smelter in the Northwest can be compared against a similar smelter in the Southwest by comparing assumed savings in electricity costs versus increased transportation costs.

Electric smelting requires about 350 kWh/ton of charge, or 1400 kWh/ton of copper. The difference in power costs between the Southwest and the Northwest is about 1¢/kWh. Thus, the saving in electricity costs

TABLE V-31

SUMMARY OF SENSITIVITY ANALYSIS RESULTS

Option	Baseline Conditions	Discriminatory Monopolistic Pricing Under Long Run Copper Price at 80 (cents/lb)[a]	85	90	100	Presence of Other Regulatory Costs[b]	Higher Transportation Costs[b]	Lower Smelter/Refinery Output[b]	Lower Variable Cost/Higher Profit[b]	Historical Cash Flow[b]	Lower Capital Investment[b]
4.1B - Minimum Control, no OSHA	Y	Y	Y	Y	Y	M	Y	Y	Y	Y	Y
4.2B - Minimum Control, with OSHA	N	M	M	Y	Y	N	N	N	N	N	N
3.1B - Intermediate; Delay; no OSHA	N	M	Y	Y	Y	N	N	N	N	N	N
3.2B - Intermediate; Delay; with OSHA	N	N	N	N	M	N	N	N	N	N	N
1.1B - Maximum Control, no OSHA	N	N	N	M	M	N	N	N	N	N	N
1.2B - Maximum Control, with OSHA	N	N	N	N	N	N	N	N	N	N	N

Notes: Y = Yes--microeconomic/financial analysis indicates that a given control option is feasible and preferred over shutdown.
N = No--microeconomic/financial analysis indicates that a given control option is not feasible.
M = Maybe--microeconomic/financial analysis indicates that a given control option is barely or marginally feasible.

a. Version A revenue stream (i.e., Lepanto falls out after 1980 and is replaced by other domestic suppliers of clean concentrates.
b. These reflect modifications of base conditions reported in the first column.

is about \$14/ton of copper. The transportation costs for bulk concentrates would be about 4-6¢/lb of contained copper, or \$80-120/ton of copper. Thus, it can be seen that the power savings are insufficient to induce electric smelting of Arizona concentrates in the Northwest. Furthermore, such concentrates could be smelted in Arizona at lower energy costs by autogeneous smelting processes such as flash smelting.

2. The Issue of Fugitives

The attainment of NAAQS using permanent controls is a preferred approach. From the viewpoint of smelter management, it is relevant to ask whether NAAQS will be met after installing the Best Available Control Technology or whether NAAQS or local standards would still be exceeded because of uncontrolled fugitive emissions requiring, in turn, additional control measures or a permanent production curtailment. The uncertainties in this area increase the risk associated with the use of BACT-caliber technology in urban areas where the fugitives problem cannot be resolved by acquiring land in the vicinity of a smelter.

I. LIMITATIONS OF ANALYSIS

In this report, we have assessed the economic impact of incremental pollution control expenditures on Tacoma under hypothesized base conditions. We have further performed a series of sensitivity analyses to examine the sensitivity of these conclusions to progressive relaxation of these base conditions. This has enabled us to explore the impact analysis problem under a reasonably wide range of conditions or combinations of conditions, to check whether the final conclusions remain the same (i.e., are "robust") or become ambiguous as these base conditions are relaxed.

While this sensitivity analysis helps define a "feasibility space" over which certain options are either feasible or not feasible, certain limitations remain. These limitations generally fall into five broad categories which are not necessarily mutually exclusive: (1) variables or factors omitted from consideration, (2) the reliability of the data used and the correctness of their extrapolation over the impact period of 1978-1995, (3) validity of the methodological approach, (4) reasonableness of the future "state(s) of the world" hypothesized for analysis, and (5) correctness for the postulated decision-making behavior on the part of Asarco.

There exist major uncertainties in the future with respect to other potential environmental regulations and associated compliance costs at Tacoma. These relate not only to costs for incremental SO_2 control and for OSHA-inorganic arsenic standards which are treated explicitly in this report, but also to other potential costs (for ambient lead, arsenic, in-plant SO_2 and other standards) which could also be incurred over the impact analysis period.

This factor increases the uncertainties at Tacoma. Our impact results are understated to the extent that these costs are not explicitly considered. (A possible way to take this factor into consideration would have been to increase the discount rate to 20% or even higher. This would not have affected the conclusions). A related point in this connection is the possibility that the costs of compliance associated with all control options considered in our analysis are understated in the following sense. The pollution control costs for existing sulfuric acid and liquid SO_2 production are a part of the baseline costs and the revenues from the sale of these byproducts are a part of the baseline revenue stream. All incremental SO_2 control options require liquid SO_2 for enrichment and assume that liquid SO_2 is available at zero cost. If liquid SO_2 were unavailable, the operating costs for all the options considered would have been significantly higher--reflecting mainly increased energy consumption.

Our analysis over the period 1978-1995 relies on numerous estimates and projections prepared (by us or by others) on the basis of professional judgment using available information as a guide. These data and projections are in the following areas:

- Incremental SO_2 control costs
- Incremental OSHA costs
- Future baseline raw materials supply to Tacoma
- Potential reduction in future baseline capacity of Tacoma if electric smelting is adopted
- Future production costs
- Future transportation costs
- Future revenues at Tacoma
- Future charges for smelting and refining in Japan, the Philippines and the Southwest
- Future concentrate production costs for Lepanto, Northern Peru, and Duval
- Shutdown costs for Tacoma

Generally speaking, our analysis leads us to believe that the conclusions reported are fairly "robust" (i.e., strong, invariant, not very sensitive) over a wide margin for the magnitude of these projections. Thus, our conclusions will not be altered significantly if somewhat different numbers are used. A different set of such numbers could be derived by other analysts by using more precise historical data and/or by using their professional judgment. We believe that it is unlikely for such numbers to fall outside the range used in the sensitivity analysis; and, if so, be in a direction such that the basic conclusions are altered. For these reasons, we believe that additional historical data is not likely to have a significant effect on the conclusions. For example, even if our estimate of net present value of shutdown is in error by several million dollars, it is not likely to alter our basic conclusions under baseline analysis. The conclusions pertaining to Options 4.2B and 3.1B, under hypothesized discriminatory monopolistic pricing on the part of Tacoma, might be altered, but this depends on the size of the difference from the estimates given here, and the extent to which high copper prices would be obtained (especially in the early years), in order to permit such a strategy.

The methodological approach used in our analysis, relying on integrated microeconomic and financial analysis principles and practice, is predicated upon rational economic behavior. This may involve at least two types of shortcomings. In the first instance, actions or reactions in real life may be more discontinuous than would be implied by theory. Moreover, certain "intangible" factors may be completely ignored in a theoretical analysis. For example, before embarking on a course of discriminatory monopolistic pricing, Asarco may have to weigh such intangibles as possible loss of "goodwill." While "goodwill" is intangible in the sense that it is difficult to quantify, it might be an important issue to Asarco given the fact that a majority of new projects in the mineral industry are joint ventures and goodwill is important for the continuation of this practice. Similarly, Asarco may not want to antagonize the Government of Peru about Northern Peru, since Asarco has a much larger equity investment in the Southern Peru Corporation of approximately $160 million.

It is not possible to define the future "state(s) of the world" (1978-1995) in a precise manner. A single unique set of future conditions, including copper prices, can neither be defined nor, of course, guaranteed for such impact analysis. There are many participants in the present analysis, each having a possibly different set of future expectations (e.g., on copper prices), different set of alternatives open to them and different perceptions of risk than may be imputed to them in the analysis here. The participants are assumed to behave in certain ways, based on theory, which may not, in reality, occur, not because of any deficiency in theory but because real life is typically more uncertain and therefore too complicated to be fully predicted through microeconomic or financial analysis. We have already pointed out how some "intangible" factors may impinge upon the analysis and the result. Legal risks that might be taken by Asarco-Tacoma in pursuing a discriminatory monopolistic pricing strategy have also been ignored. Other factors have also been omitted from consideration, to keep the analysis under manageable proportions. For example, Lepanto, rather than paying high toll charges over the period 1978-1980, as Tacoma's monopolistic pricing behavior would require, might instead produce and stockpile its concentrates until the new Philippines smelter opens. These points, taken together, cumulatively indicate that the revenue streams estimated for Tacoma over the period 1978-1995 under Tacoma's hypothesized discriminatory monopolistic pricing behavior represent upper-bounds under each assumed long-run copper price level. However, if under these "extreme" conditions a control option fails to be considered viable, then, it would seem to us that there is little likelihood for that option to be in fact viable (i.e., we can reject the hypothesis that a given option is viable with a high degree of confidence).

Finally, it should be noted that any analysis by a third party cannot capture in detail Asarco's full-range of decision options, their perceptions of risk and uncertainty and even their analytical approach in examining the Tacoma smelter/refinery situation. However, while the details of Asarco's thinking may not have been fully captured, we believe our analytical approach represents a reasonable approximation of the central logic of Asarco's decision-making in the area considered in this report.

APPENDICES

APPENDIX A

TYPICAL SMELTING AND REFINING SCHEDULE FOR COPPER CONCENTRATES

A. INTRODUCTION*

The actual price paid by a smelter and refinery for a particular concentrate is a function of the composition of that particular concentrate, the overall composition of the entire smelter and refinery charge, and the effect the concentrate exerts on their operations. Smelters with varied sources of ores and concentrates generally have lower recoveries and might offer less attractive terms. Similarly, a concentrate considered undesirable by one smelter might be considered desirable by another because of the composition of other concentrates and be offered a "friendly" contract. The typical contract shown below has the structural features of actual smelting and refining contracts in the U. S. and abroad.

The following features of these contracts are important:

1. The concentrate value (and mine profits) vary with the price of the refined metal. The charge for smelting and refining does not vary with the price of the refined metal.

2. The smelting and refining charges increase in accordance with specified formulae with increases in energy and labor costs.

3. Contracts fall into two categories: A "custom" contract involves the outright purchase of the concentrate by the smelter and refinery. Under a "toll" contract, the smelter will smelt and refine the concentrate for a fee and return the recovered metals. In either case, the formulae for calculating smelting and refining charges are the same.

B. DEFINITIONS AND TERMS

<u>Ton</u>: Dry short tons of 2000 lb; unless otherwise stated, all tons refer to dry tons of concentrates.

<u>OZ</u>: Troy ounce (31.1035 g)

<u>Unit</u>: One hundredth of a ton; 20 lb.

---

* See also: C. F. Page, <u>Engineering and Mining Journal</u>, June 1965, for old smelter schedules, pp. 199-205.

Delivery: FOB smelter. Freight and insurance to be paid and guaranteed by the seller. An extra unloading and sampling charge is assessed for small shipments. The date of delivery is the date on which unloading at the smelter is commenced.

Title: For toll contracts, the title to all accountable metals (metals to be returned) remains with the shipper (mine) at all times. For custom contracts, title shall pass to the buyer (smelter) after delivery, as defined above.

Weighing, Sampling, Assaying: Smelter weights and samples govern settlement. The shipper, at his own expense, is entitled to be represented at the smelter for sampling and weighing. The final sample is split into four portions: shipper, smelter, umpire and reserve. If shipper and smelter agree within splitting limits, the average of the two is used as settlement assay. If they differ by more than the splitting limit, the umpire sample is analyzed by an umpire agreeable to both parties and the middle of the three assays is used for settlement.

C. ACCOUNTING FOR METALS (Metals Paid for or Returned)

Copper: From copper assay, deduct one unit and pay for (or return) 97-100% of the remaining copper.

Gold: If gold content is at or over 0.03 oz/ton, pay for (or return) 98% of gold content. No accounting shall be made for gold content if less than 0.03 oz/ton.

Silver: If silver content is 1 oz/ton or over, pay for (or return) 95% of silver content. No accounting shall be made for silver content, if less than 1 oz/ton.

D. PRICES

Copper: Metals Week, U. S. Producer refinery quotation, or average of 4 LME quotations (prompt, 3 months, bid, asked) averaged for the calendar month, 90 days after the date of delivery. For toll contracts, return metal after 90 days.

Silver: Monthly average of Handy & Harmon, New York, price adjusted to the applicable basis or average of LME silver settlement for the same time period used for copper settlement.

Gold: Monthly average of London gold settlement.

E. CHARGES, DEDUCTIONS AND PENALTIES, ESCALATIONS

Base Smelting Charge: \$30-60/net dry ton of concentrates.

Base Refining Charge: 4-8¢/lb of copper accounted for.

Metal Returning Charges: Some toll contracts include additional charges for returning the metals.

Penalties for Impurity Content: Added to base smelting charge.

Lead: 1 unit free - excess charged at \$0.25/unit.

Zinc: 5 units free - excess charged at \$0.25-0.30/unit.

Nickel and Cobalt: 0.5 units free - excess charged at \$0.50-2.50/unit.

Arsenic: 0.5 units free - excess charged at \$0.25-1.00/unit.

Antimony: 0.2 units free - excess charged at \$0.25-1.50/unit.

Bismuth: 0.05 units free - excess charged at \$0.50/lb.

Escalations: The base smelting charge and refining charge are escalated with changes in labor and fuel costs.

F. OTHER CLAUSES

Most contracts also provide a schedule for the range of concentrate tonnages that can be shipped per month.

All contracts contain a "Force Majeure" clause, which will cause a suspension of the smelter schedule terms when operations at either the mine or smelter are interrupted or significantly affected by acts of God, acts of governmental authority, accidents, labor disruptions, or other factors.

APPENDIX B

SULFURIC ACID AND SULFUR DIOXIDE

A. MARKET OUTLOOK FOR SULFUR DIOXIDE AND SULFURIC ACID IN THE NORTHWEST

1. North American Sulfur, Sulfur Dioxide and Sulfuric Acid

a. Sulfur

North America accounts for more than 25% of total world sulfur consumption. The U. S., in turn, accounts for approximately 85% of North American consumption. Imported sulfur supplies about 10% of total U. S. consumption, but imports of sulfuric acid represent only about 1% of U. S. consumption. This is because, while sulfur is a commodity chemical which enters significantly into international trade, the marketing of sulfuric acid, and to some extent sulfur dioxide, is limited by the hazard associated with handling and the expense associated with their shipment to distant markets.

Sulfuric acid and sulfur dioxide weigh three times and twice as much, respectively, as the equivalent weight of sulfur. Both are shipped in tank cars, while sulfur can be shipped molten in tank cars or in solid form. The storage of elemental sulfur in solid or molten form is cheaper and less hazardous. Finally, the production of sulfuric acid or SO_2 generates waste heat which is recovered as byproduct steam. For all of these reasons, a large percentage of sulfuric acid and SO_2 production is captive and much of the production is consumed within 200 miles of the producing point.

Approximately 85% of U. S. sulfur is converted to sulfuric acid, mainly for use in production of fertilizers. In addition to sulfuric acid, other uses for sulfur include the manufacture of carbon disulfide, phosphorus pentasulfide, pulp and paper products and vulcanized rubber. Although a considerable amount of research has been done on possible new applications for sulfur (e.g., as a partial replacement for bitumen in asphalt), none of these new uses has achieved commercial success to date.

North American sulfur demand has historically experienced growth at a rate of approximately 4% per annum. Supplies of sulfur have grown rapidly since the 1950's when new sources of sulfur appeared in the form of non-discretionary, byproduct sulfur derived from fossil fuels, and byproduct sulfuric acid produced during the processing of nonferrous metal ores. This byproduct sulfur is subject to completely different costs of production than is discretionary Frasch sulfur, which, until the 1950's, represented the major portion of North American production. Currently, however, discretionary and non-discretionary sulfur production are of nearly equal importance in North America.

Canada has historically accounted for the majority of recovered non-discretionary sulfur in North America. This sulfur is a byproduct of gas and crude oil refining operations in Alberta. Much of this sulfur is being stockpiled in Canada because of logistics and regulatory problems associated with its shipment to potential markets. Nevertheless, this stockpile, the size of which now exceeds the current annual U. S. consumption of sulfur, must be viewed as a potential future supplement to other recovered sulfur values in the Northwest.

Non-discretionary elemental sulfur from sour gas or crude refining is usually lower in impurities than natural Frasch sulfur. Both can be stockpiled easily and compete directly against each other. Non-discretionary sulfuric acid and liquid SO_2 compete against elemental sulfur, but suffer from the following handicaps: Their storage and handling is more hazardous and more expensive; their transportation costs are higher and their use does not provide byproduct steam obtainable when elemental sulfur is burned. Thus, sellers of byproduct SO_2 or sulfuric acid have to adopt a strategy of selling their product in the nearest market (to minimize transportation costs) at a discount below the equivalent product derived from elemental sulfur. The discount compensates for the absence of byproduct steam credits, usually higher impurity (heavy metals, etc.), off-color, and lower reliability of supply compared to a captive plant.

In general, the production of sulfur and its derivatives is expected to increase more rapidly than demand for these products. This is particularly true in the West where demand for sulfur is relatively limited but where production of recovered sulfur from fossil fuels refining is extensive. Particularly important are the production of sulfur from refining Canadian sour gas in Alberta and the refining of Middle Eastern crude oils in California refineries. The refinery production of sulfur in California will decline if and when the lower-sulfur Alaskan crudes displace the Middle Eastern crude oils. In addition, air pollution control regulations require a reduction in the emissions of sulfur dioxide from smelters, refineries, power plants and other facilities. This will lead to an increase in the production of byproduct sulfur values in the Northwest, as in the U. S. as a whole.

b. Sulfur Dioxide

Sulfur dioxide is produced by burning elemental sulfur. The single largest use for sulfur dioxide is in the production of sodium hydrosulfite which in turn is used as a bleaching agent in the production of textiles, paper, and clay. The use of SO_2 in pulp and paper manufacture is dwindling because sulfite-based pulping is now technically obsolete. Other uses for sulfur dioxide, including refining and food processing, are expected to offset the lower demand in pulp and paper. The result will be that SO_2 demand is expected to increase at an annual rate of approximately 4-5%

during the next five years. Current North American sulfur dioxide (SO_2) capacity is approximately 251,000 tons/year, as indicated in Table B-1. A complete usage breakdown for sulfur dioxide is presented in Table B-2.

The Northwest accounts for a relatively large portion of U. S. sulfur dioxide capacity. In fact, Asarco's Tacoma capacity of 70,000 tons/year (production has been about 50% of capacity) is equivalent to one-third of total U. S. consumption. Scott Paper Company, which until recently produced sulfur dioxide in Washington, is believed to have put its plants on a standby basis and is purchasing Asarco's Tacoma production for all its needs. Another Western sulfur dioxide plant, which has been removed from current capacity lists, but which is reportedly still in operation, is a small plant operated by Virginia Chemicals in Selby, California. This plant, with a capacity of approximately 14,000 tons/year, is expected to be shut down soon, as sulfur dioxide from Tacoma takes over those markets currently served from this location. Marketing of the sulfur dioxide from the Tacoma smelter is currently handled under a ten-year contract by Virginia Chemicals. Finally, Cominco operates a 60,000 tons/year sulfide dioxide plant at Trail, British Columbia which, reportedly, supplies some of the sulfur dioxide requirements for the Northwest.

As was indicated in Table B-1, approximately 70% of sulfur dioxide production is used in the production of bleaches or related chemicals. The largest single bleaching application is in the pulp and paper industry. Another important use of Northwestern sulfur dioxide is for the production of wine and other food products in California. The total western U. S. market for sulfur dioxide is estimated to be approximately 30,000 tons/year. Any additional production not consumed in the West is shipped to the Eastern markets with a shipping cost of about \$45/ton. When valued at \$130/ton (a published list price in Chemical Marketing Reporter), sulfur dioxide can be shipped longer distances than sulfuric acid. This is because of its lower weight and higher value on a sulfur equivalent basis.

In the Northwest, however, most of the SO_2 is sold only by displacing elemental sulfur, which as described earlier, is abundant in this region. About a third of Tacoma's production, which is sold in the Northwest, displaces elemental sulfur and realizes a price which is tied to the sulfur price and is a small fraction of the published list price. Another third of Asarco's SO_2 output is sold in California and the West at a price which reflects its form value but which is well below the list price. The remainder which is shipped East, displaces elemental sulfur from this market. It appears that Asarco does not realize netbacks to Tacoma sufficient to cover the out-of-pocket costs of making SO_2 in any of its significant markets. We believe it is unlikely that Asarco will be able to break even on SO_2 sales in the near future.

c. <u>Sulfuric Acid</u>

Sulfuric acid is by far the most important U. S. industrial chemical in terms of annual production volume. Although 1975 production exceeded 30 million tons, this represented a drop of more than 7% from the record level of 33 million tons produced in 1974. As a mature chemical commodity,

TABLE B-1

NORTH AMERICAN SULFUR DIOXIDE CAPACITY

Producer	Location	Annual Capacity (thousand tons)
A. Western U.S. & Canadian		
Asarco, Inc.	Tacoma, Washington	70***
Cominco	Trail, British Columbia	60
Scott Paper Co.	Anacortes, Washington*	-
	Everett, Washington*	-
Virginia Chemicals	California**	14
	Subtotal	144
B. Eastern U.S. Capacity		
	Subtotal	107
	Total	251

*Plants not in operation.

**Plant scheduled to shut down.

***70,000 tons is design rate; production has been about 35,000 tons/year.

Source: Chemical Marketing Reporter and private communication with industry.

TABLE B-2

SULFUR DIOXIDE END USE

End Use	Percent of Total
Hydrosulfites, other chemicals	45
Pulp and paper	25
Metal and ore refining	11
Soybean protein	8
Oil refining	6
Miscellaneous	5
Total	100

Source: Chemical Marketing Reporter and Arthur D. Little, Inc., estimates based on private communication with industry.

the long-term growth for sulfuric acid has historically been about 3% per annum. Between 1965 and 1975, the growth rate was depressed to an average of only 2% per annum due to the low level of 1975 production. As indicated earlier, foreign trade is relatively unimportant, with imports equal to 1% of production in 1975 and exports at approximately half this level. In 1975, Canada and Mexico, together, received 80% of U. S. sulfuric acid exports. In the same year, 93% of U. S. imports came from Canada.

As indicated in Table B-3, U. S. sulfuric acid capacity in 1975 was approximately 46 million tons. The vast majority of this capacity (84%) is in the Gulf Coast and eastern U. S. The Northwest, the Pacific Coast and the Southwest, together, account for only 16% of U. S. sulfuric acid capacity.

By far the most important use for sulfuric acid is in the production of phosphate fertilizers, which account for approximately 55% of U. S. sulfuric acid demand. Other uses accounting for more than 3% of total demand are the alkylation of hydrocarbons (5%) and the production of titanium dioxide, ammonium sulfate and alcohols (approximately 4% each). A more complete description of current sulfuric acid use is given in Table B-4.

2. Sulfur, Sulfur Dioxide and Sulfuric Acid in the U. S. Northwest

a. General Outlook for Sulfur Balance in the Northwest

As indicated in Table B-3, Western U. S. producers of sulfuric acid account for approximately 7.6 million tons or 16% of total U. S. capacity. Sulfuric acid producers in the Northwest including Washington, Montana, Idaho, and Wyoming account for approximately 2 million tons or 5% of total U. S. capacity. Finally, the three sulfuric acid producers in Washington State, with a combined capacity of 167,000 tons, account for less than 0.4% of U. S. capacity. If 90% of the SO_2 emissions are controlled at Tacoma, the incremental sulfuric acid production would be approximately 132,000 tons/year. This would increase sulfuric acid capacity in Washington to approximately 300,000 tons/year.

Potential new Western sulfuric acid capacity through 1979 as indicated in Table B-5, is approximately 1.8 million tons annually. The incremental acid capacity at Tacoma (if the plant achieves 90% sulfur control) would represent approximately 7% of this total. For the West as a whole, an increase from 7.6 million tons of annual capacity in 1975, to 9.4 million tons in 1979, represents nearly a 25% gain in regional capacity. This is equivalent to an average annual growth in capacity of approximately 5%. This rate is at the high end of the range of likely future U. S. sulfuric acid demand growth of 3-5% per annum. It is also significantly more rapid than likely increases in demand in the West. For example, a U. S. Bureau of Mines forecast of Western phosphate rock growth indicates that growth will be at a rate of about 3-5% per annum between 1970 and 1990.*

*"Development of Phosphate Resources in Southeastern Idaho," Volume I, Draft Environmental Impact Statement, Dept. of Interior, 1976.

TABLE B-3

U. S. SULFURIC ACID CAPACITY - 1975

Producer	Location	Annual Capacity (thousand tons)	
A. Washington State			
Allied Chemical	Anacortes, Washington	92	
Asarco, Inc.,	Tacoma, Washington	53	
Georgia-Pacific	Bellingham, Washington	22	
	Subtotal	167	
B. Other Northwest			
Anaconda Co.	Anaconda, Montana	231	
Beker Industries	Conda, Idaho	600	
Gulf Resources	Kellogg, Idaho	250	
Phelps Dodge	Jeffrey City, Wyoming	35	
Phelps Dodge	Riverton, Wyoming	75	
J.R. Simplot	Pocatello, Idaho	800	
	Subtotal	1,991	
C. California		1,702	
D. Southwest		3,787	
E. Western U.S.			7,647
F. Other U.S.			38,748
	Total		46,395

Source: Directory of Chemical Producers and Arthur D. Little, Inc., estimates based on private communication with industry.

TABLE B-4

SULFURIC ACID END USE

Fnd Use	Percent of Total
Fertilizer	56
Alkylation	5
Titanium Dioxide	4
Ammonium Sulfate	4
Alcohols	4
Copper Leaching	3
Hydrofluoric Acid	3
Aluminum Sulfate	2
Cellulosics	2
Steel Pickling	1
Surface-Active Agents	1
Uranium Ore Processing	1
Miscellaneous	14
Total	100

Source: Arthur D. Little, Inc., estimates based on published industry statistics.

TABLE B-5

POTENTIAL NEW WESTERN U. S. SULFURIC ACID CAPACITY

(thousand tons/year)

Producer	Location	Incremental Capacity 1977	1978	1979+
Allied Chemical	Richmond, Calif.			140
Anaconda**	Anaconda, Mont.	120		
Asarco, Inc.**	East Helena, Mont.	140		
Asarco, Inc.**	Tacoma, Washington			130
Kennecott**	Garfield, Utah		420	
Occidental	Lathrop, Calif.			200
Phelps Dodge**	Hidalgo, New Mexico	250		
Bunker Hill	Kellogg, Idaho			150
Valley Nitrogen	Helm, Calif.	355		
	Annual Total	865	420	620
	Total Potential Increment		1,285	1,905*

*A 23% increase over 1975 regional capacity, of which over half is non-discretionary; equivalent to 780K tons of phosphoric acid (P_2O_5).

**Non-discretionary capacity.

Source: Arthur D. Little, Inc., estimates, EPA/Region X.

3. The Outlook for Incremental Sulfuric Acid Produced at Tacoma

a. Marketing

Many large consumers of sulfuric acid choose to purchase sulfur and produce sulfuric acid on-site in order to achieve low price, high quality and dependability. In addition to these benefits, the producer of this captive sulfuric acid can use excess steam generated during sulfur combustion, for example, to concentrate his phosphoric acid product. At $1.25 per million Btu's this byproduct steam represents an energy credit of approximately $5.00/ton of sulfuric acid produced. For byproduct smelter acid to displace this acid it must not only be sold at less than the integrated acid producer's variable cost, but it must also compete with this energy credit on a delivered cost basis.

The producers of non-discretionary byproduct sulfuric acid (or SO_2) have to sell their product in competition with the same products often produced in captive plants by the user. The general strategy that has to be followed by these producers is to displace discretionary acid derived from elemental sulfur in the nearest market in order to minimize transportation costs. This displacement is achieved by selling non-discretionary acid at a discount. This discount has to compensate for the absence of byproduct steam credit, higher impurity content, and lower reliability of supply (actual or perceived) compared to a captive plant. While the quality of smelter acid has been improved recently, some specialized markets such as alkylation are simply not available to smelter acids. In addition, marketing sulfuric acid in the West is generally more complex than, for example, on the U. S. Gulf Coast. One reason is because of the general lack of large single customers to purchase available supplies. One industry source estimates that sulfuric acid from Asarco's Tacoma smelter is now sold to as many as 30 different consumers in Washington and other Western states. Asarco's acid is currently marketed by Stauffer Corporation which arranges for the sale and delivery of the acid.

Because of high shipping costs relative to the price of sulfuric acid, most sulfuric acid has been consumed within several hundred miles of the producing point. Only with the recent advent of regional imbalance in sulfuric acid supply and demand has more distant rail shipment and, to some extent, ocean transport, become more important. Estimated costs for rail shipment of sulfuric acid from Tacoma to selected markets are presented in Table B-6. As will be discussed below, the shipping cost alone for moving sulfuric acid from Tacoma to Houston, is equal to nearly 70% of the current selling price for sulfuric acid in Houston.

The only alternative to displacing acid derived from discretionary sources is neutralization. Order-of-magnitude costs estimated in Section III suggest that under most conditions the shipment of smelter acid to distant markets (1000-3000 miles away) is a lower cost strategy than neutralization. The long-term storage of acid is not a viable option because of the hazard associated with this approach.

TABLE B-6

ESTIMATED RAIL COSTS FROM TACOMA TO SELECTED MARKETS

(dollars/ton)

Market Destination	Approximate Rail Mileage	Rate ¢/ton Mile	Approximate Rail Cost
San Francisco, Calif.	885	1.8	16
Los Angeles, Calif.	1,350	1.6	22
Pocatello, Idaho	870	1.8	16
Garfield, Utah	1,040	1.6	17
Houston, Texas	2,590	1.3	34
Chicago, Illinois	2,350	1.4	33

Source: Arthur D. Little, Inc., estimates.

b. Demand

As previously indicated, more than 50% of U. S. sulfuric acid production is consumed in the manufacture of phosphate fertilizers. Therefore, demand for sulfuric acid is very sensitive to fertilizer demand. This is even more true in the Northwest where the fraction of sulfuric acid going to phosphate production is expected to increase substantially as the Western phosphate fields are developed.

An estimate of 1975 and projected 1985 capacity for Western U. S. phosphoric acid capacity is presented in Table B-7. The current capacity level of 837,000 tons of P_2O_5 is expected to increase to approximately 1.2 million tons by 1985. This is equivalent to an average annual growth rate of 3.7%. In comparing the expected incremental phosphoric acid capacity of 363,000 tons with the amount of sulfuric acid which would be required to satisfy the requirements for this capacity, it is interesting to note that only about 815,000 tons of sulfuric acid would be required. This is less than half of the incremental sulfuric acid which may be available as early as 1979 -- 6 years before Western phosphoric acid capacity is expected to reach the 1.2 million ton level. This also assumes that all of the incremental sulfuric acid is used in phosphoric acid production and that phosphoric acid producers choose not to purchase sulfur from Canada or California for on-site production of sulfuric acid.

Although there are many other important uses for sulfuric acid, very few of these end uses have attractive growth prospects. The use of sulfuric acid in refineries for alkylation is expected to be level or decrease gradually. Also, because of pollution problems associated with the sulfate process for the manufacture of titanium dioxide, this segment represents a no-growth market for sulfuric acid. In any case, there are no sulfate process plants in the Western U. S.

Alum, or aluminum sulfate is an important sulfuric acid derivative in the Northwest. However, this is a relatively mature inorganic chemical with growth generally limited to a rate of about 2% per annum. Because aluminum sulfate is an important chemical for the manufacture of pulp and paper and also because alum production consumes sulfuric acid, new alum plants have been located near paper mills and sources of byproduct sulfuric acid. The demand outlook for alum is limited and current capacity is adequate for present and projected demand.

Several other relatively important products derived from sulfuric acid also have limited growth prospects. For example, the production of hydrofluoric acid requires sulfuric acid but the two most important applications for hydrofluoric acid, fluorocarbons and aluminum fluoride, have limited or negative growth potential because of efforts to control fluorine emissions to the environment. Sulfuric acid is also used in the production of cellulosic fibers and films, however, this market faces long-term decline.

TABLE B-7

FORECAST OF WESTERN U. S. PHOSPHORIC ACID CAPACITY

(thousand tons P_2O_5)

Producer	Location	Capacity 1975	1985	Growth Rate (p.a.a.)
Becker	Conda, Idaho	250		
Collier Carbon	Nichols, California	8		
Duval	Hanford, California	20		
Gulf Resources	Kellogg, Idaho	32		
Occidental	Lathrop, California	40		
J.R. Simplot	Pocatello, Idaho	280		
Stauffer	Garfield, Utah	100		
Valley Nitrogen	Helm, California	100		
Valley Nitrogen	Bena, California	7		
	Total	837	1200	3.7%

Source: Directory of Chemical Producers and Arthur D. Little, Inc., estimates, based on private communication with industry.

Uranium ore processing and copper leaching represent two relative bright areas in the sulfuric acid end use scheme. Unfortunately, these two applications, combined, account for only about 4% of sulfuric acid demand. Copper leaching has recently become more attractive, partially because of the ready availability of byproduct sulfuric acid from smelter gases and partially because of hydrometallurgical process developments for metal recovery from ore tailings. Uranium ore processing while promising, faces many uncertainties as the U. S. gradually increases its dependence on nuclear power. One nonferrous metal company representative places potential sulfuric acid demand for this application at about 15,000 tons/year in the Northwest.

In summary, the expected growth in sulfuric acid demand in the Northwest is much lower than the expected growth in capacity during the next ten years. With the incremental supply likely to be larger than incremental demand, any additional sulfuric acid from Tacoma must displace current demand in the Northwest, thus disrupting this market, or move into more distant, possibly export, markets.

c. Prices and Netbacks

In this section, we calculate the maximum netbacks Tacoma can obtain if it sells incremental sulfuric acid in the regional demand centers by displacing acid generated by burning elemental sulfur. The netbacks to Tacoma are calculated by subtracting transportation costs from estimated average acid prices.

A summary of current and historic sulfuric acid prices is presented in Table B-8. These prices generally represent average U. S. prices with current prices in the Northeast and Mid-West closer to $55/ton. Smelter acid is generally available in the Southwest at approximately $15/ton f.o.b. smelter. Because of relatively low rail rates in the Southwest, smelter acid from southern Arizona or New Mexico can be shipped either to Los Angeles or to Houston for approximately $12/ton, resulting in a delivered price of approximately $27/ton. Acid from Tacoma could compete in Los Angeles with this acid from the Southwest only by accepting a netback of $5/ton ($27 less $22 rail cost from Tacoma to Los Angeles). Based on the estimated rail costs in Table B-7, sulfuric acid from Tacoma could compete with smelter acid from the Southwest in the Houston market only by subsidizing the $34 rail cost -- resulting in a negative netback of -$7. If demand exists, it would appear to be more attractive to ship Tacoma acid to Chicago where it could compete with acid from the Southwest and achieve a netback of perhaps $10 to $15 per ton.

The potential for inducing a phosphate fertilizer manufacturer in, for example, Idaho to shut his acid plant and purchase smelter acid from Tacoma does not appear great since the estimated freight rate of $16/ton is roughly equivalent to the estimated cost of producing sulfuric acid in Pocatello, based on a delivered sulfur cost of approximately $50/ton. Since this does not include the estimated $5/ton steam credit, a subsidy for the rail shipment of acid from Tacoma to Pocatello would appear to

TABLE B-8

PRICE HISTORY FOR SULFURIC ACID

(dollars/ton)

Year	Sulfuric Acid[a]
1960	24
1964	24
1968	34
1972	36
1976	48

[a] Average list price, 100% basis, FOB works, tanks.

Source: Chemical Marketing Reporter.

be necessary, again resulting in a negative netback. Similar logic would hold for most Western phosphoric acid producers having captive sulfuric acid plants. These estimated netbacks for Tacoma are summarized in Table B-9.

4. Conclusions

Because of the relatively rapid increase in potential sulfuric acid supplies in the West relative to expected demand, incremental sulfuric acid from Tacoma would be forced to compete for demand in more distant, perhaps export, markets. However, most foreign and domestic markets for sulfuric acid will be facing the same imbalance that is expected to develop in the U. S. Northwest. For example, Japan which has historically imported large quantities of sulfuric acid, began exporting sulfuric acid in significant quantities in 1975.

An analysis of sulfuric acid prices and rail costs to various domestic markets indicates that netbacks to Tacoma vary from $-7 to +15 per ton of acid. The highest netback is based on a distant market (Chicago) and this netback would only be available if byproduct sulfuric acid from another source cannot be delivered at a more competitive price. In view of this analysis, the average netback on incremental sulfuric acid production at Asarco's Tacoma Smelter is likely to be $0 to $5, i.e., the acid can be sold in a number of potential markets for the cost of delivery plus $0 to $5.

In view of the cost for neutralization of byproduct sulfuric acid estimated in a subsequent section (Section C), at about $20-25/ton, it appears that the smelters would choose to sell acid at a $0 to $5 netback and utilize the neutralization facility as a standby to be used in periods of high copper demand and low acid demand.

B. CURRENT COSTS OF EMISSION CONTROL AT TACOMA

1. Acid Plant

Table B-10 summarizes the costs of making acid at Tacoma. Table B-11 presents a list of new equipment installed at the acid plant.

2. Liquid SO_2 Plant

Table B-12 summarizes the costs for liquid SO_2 production at Tacoma. In Tables B-10 and B-12, it should be noted that "tools, repairs and miscellaneous supplies" amount to less than 4% of capital investment. When engineering estimation techniques are used, such costs are usually estimated at 4-5% of capital investment.

TABLE B-9

ESTIMATED NETBACKS TO TACOMA

($/ton acid)

Destination	Value at Destination	Less Rail Cost	Netback to Tacoma
Los Angeles	27	22	5
Houston	27	34	-7
Chicago	43-48	33	10-15
Pocatello	11	16	-5
Average			0-15

Source: Arthur D. Little, Inc. estimates.

TABLE B-10

COSTS OF ACID PRODUCTION AT TACOMA

Operating Costs (1975$)	$/Ton H_2SO_4
Raw Material: Vaporize Liquid SO_2	1.98
SO_2 from Converters	--
Operating Labor and Supervision (including fringe benefits)	4.67
Utilities: Power	0.85
Fuel Oil	0.66
Gas	0.41
Tools, Repairs & Miscellaneous Supplies	2.22
Total Direct Costs	10.79
Indirects	3.05
Depreciation	2.31
G&A	0.59
Overhead	2.90
Total Unit Operating Costs	19.64

Source: Asarco, Inc.

TABLE B-11

NEW EQUIPMENT INSTALLED AT THE ACID PLANT

(1951-1976)

Item	Year
40-ton oleum tank	1949
Additional storage	1951-1952
Battery acid facilities	1953
Repair and replace blower impeller	1963
Replace spray chamber	1965
Replace preheater	1965
Add electrical control on Cottrell system; increase blower HP	1967
Replace preheaters; remove SO_3 cooler	1970
New absorption tower; new tail gas flues	1973
Hot heat exchanger; new SO_3 vaporizer; remove Labbé coolers	1973
Voltage controller or Cottrell	1974
Replace cast iron piping with acid coolers	1974
Bypass flues	1975
New drying tower	1976

Source: Asarco, Inc., EPA/Region X

TABLE B-12

COST OF LIQUID SO_2 PRODUCTION AT TACOMA

Operating Costs (1975$)		$/Ton SO_2
Raw Materials:	Acid	0.07
	DMA	5.89
Operating Labor and Supervision (including fringe benefits)		6.47
Utilities:	Steam	4.79
	Power	3.53
Tools, Repairs & Miscellaneous Supplies		15.12
Total Direct Costs		35.87
Indirects		11.72
Depreciation		7.95
G&A		1.97
Total Operating Costs		57.51

Source: Asarco, Inc.

C. ACID NEUTRALIZATION COSTS

In this Section, we estimate "ball park" acid neutralization costs for a plant with a capacity up to 800 tons/day of acid. Such a plant would probably not be used on a continuous basis, but only during those periods when acid cannot be disposed in any other way. We feel that an acid neutralization plant would be located away from the smelter, e.g., in eastern Washington, so that the sludge from neutralization can be stored indefinitely at site in a lined pond. The use of lined ponds for such storage is consistent with current trends in effluent limitation guidelines.

The M&S index was used to escalate plant costs to 1978. Pond costs usually vary from $4,000-35,000 an acre, depending on the terrain and whether they are lined or not. We have used average costs of $25,000 an acre for a lined pond. Some of the operating unit costs were: limestone at $8 a ton delivered, operating labor at $10.65 an hour and supervisory personnel at $20,000 a year. (If such a facility were actually built, it would probably be run with Tacoma smelter employees on overtime.)

The capital and operating costs are summarized in Table B-13. Disposal costs are of the order of $21.00 a ton of acid at the disposal site. The shipping of acid to this site would entail an additional transportation charge of $4.00/ton of acid resulting in total acid disposal costs of the order of $25/ton acid.

TABLE B-13

ORDER-OF-MAGNITUDE COSTS OF ACID NEUTRALIZATION FOR A 800 TPD PLANT

(1978$)

CAPITAL COSTS		
Purchased Equipment Costs (PEC)		$ 814,350
Installed Plant Cost (3 x PEC)		2,443,050
300 Acre Pond @ $25,000 an acre		7,500,000
Total Capital Costs		$9,943,050
VARIABLE COSTS		$/Day
Utilities		
Cooling Water	11 MGal @ $0.025/MGal	$ 0.30
Power	4300 kw, 24 hr @ $0.006/kwh	619.20
		$ 619.50
Chemicals	890 tons @ $8.00/ton	$ 7,120.00
Operating Labor		
Labor	2 men, $10.65/hr, 24 hr	$ 511.20
Supervision	15% direct labor	76.70
Total Direct Labor		$ 587.90
Payroll Overhead	20% direct labor costs	117.60
		$ 705.50
Maintenance and Supplies	5% of capital cost	1,484.00
Plant Overhead	50% operating labor plus maintenance and supplies	1,093.00
Total Variable Costs		$11,022.00
FIXED COSTS		
Depreciation, Interest, Taxes and Insurance	21.5% of capital costs	$ 6,381.40
Total Disposal Costs		$17,403.40
		= $21.75/Ton Acid

Source: Arthur D. Little, Inc. estimates.

APPENDIX C

ARSENIC TRIOXIDE (As_2O_3)

A. INTRODUCTION

Arsenic trioxide (As_2O_3) is produced as a byproduct from the flue dusts obtained during pyrometallurgical extraction of copper, lead, gold or silver ores. Asarco's Tacoma smelter is one of the few processors of high arsenic-containing raw materials in the world and is the only producer of byproduct As_2O_3 in the United States.

B. BYPRODUCT As_2O_3 PRODUCTION

Arsenic is available commercially primarily as arsenic trioxide (As_2O_3) and is known as white arsenic. Usually, this commodity designation is reserved for arsenic trioxide which is at least 99% pure. Crude arsenic (sometimes referred to as black or gray arsenic) usually ranges in purity from 95-98% As_2O_3. In the range 98-99%, the differentiation between crude and refined arsenic (or between black and white arsenic) can depend upon color or other physical characteristics, rather than arsenic trioxide purity.

At Tacoma, flue dusts from roasters and reverb containing arsenic are fed to the Godfrey roasters. The arsenic trioxide volatizes and is passed through arsenic settling kitchens (of which there are three), where the arsenic trioxide is condensed. A very small fraction of As_2O_3 is further processed in a reduction plant and shipped as arsenic metal. Tacoma's production of arsenic trioxide has averaged about 11,000 short tons/year, of which about 7,000 short tons has been in the form of crude arsenic trioxide and 4,000 short tons has been in the form of refined arsenic trioxide. Production of metallic arsenic has averaged only about 200 short tons/year.

C. MAJOR PRODUCERS OF As_2O_3

In addition to the United States (i.e., Tacoma), the major current producers of byproduct As_2O_3 are Sweden, France, Southwest Africa, the U.S.S.R., Mexico and Peru.

Sweden: Sweden is the largest supplier of arsenic trioxide worldwide (18,200 short tons in 1973) and is the largest foreign U. S. supplier. The Swedish arsenic is produced at the Ronnskar Works of Boliden AB, as a byproduct of smelting of copper concentrates and from arsenical dusts stockpiled from past operations (smelting arsenical gold concentrates from the Boliden mine).

France: In France, much of the output of over 10,000 short tons in 1973 was produced by two producers.

Southwest Africa: According to the U. S. Bureau of Mines, output of As_2O_3 in Southwest Africa reached 8,981 short tons in 1973, produced by the Tsumeb Mine and Smelter. In 1968-1969, the production of arsenic trioxide from Tsumeb was about 2,500 tons per year. From 1970 through 1972, it increased to about 4,000 tons per year. It therefore appears that byproduct arsenic production at Tsumeb has increased significantly.

U.S.S.R.: The U. S. Bureau of Mines has estimated that in 1973 the U.S.S.R. produced 7,990 tons of arsenic trioxide. This is believed to have been produced as a byproduct of the smelting of metallic ores, including the arsenic-cobalt ores of the Khovu-Aksink deposit.

Mexico: The U. S. Bureau of Mines reports that the production of arsenic trioxide in Mexico totaled 4,830 tons in 1973, representing a significant decline in output since 1971. Production over the period 1967-1971 ranged from 7,000 to 13,000 short tons per year.

Peru: The U. S. Bureau of Mines estimates that 1,200 tons of arsenic trioxide equivalent were produced from Peruvian mines in 1973. Presumably this does not include 1,700 tons of As_2O_3 equivalent shipped to the Tacoma plant in the form of Northern Peru concentrates.

We understand that a large quantity of arsenic trioxide is handled at the Oroya smelter of Impresa Minera del Centro del Peru (which was the Cerro de Pasco operation prior to its nationalization in 1973). Oroya has always handled significant amounts of arsenic-containing materials. Even in the mid-50's, arsenical dusts were treated to recover contained arsenic values. Some calcium arsenate and arsenic trioxide was produced for local sales. The remaining dust was and is still being stockpiled.

The supply of arsenic-containing dusts has been in excess of the demand for refined As_2O_3 and surplus dust has been stockpiled or buried[1]. The producers of refined As_2O_3 have usually maintained low prices and have also maintained stockpiles of flue dust or refined As_2O_3. In general, the absolute value of the As_2O_3 price has been dictated primarily by the size of the inventory of refined As_2O_3. Typically, prices have decreased when major producer inventory became very high. In the last three years, inventories have decreased very significantly because of strong demand in spite of large price increases.

D. CONSUMPTION TRENDS IN THE UNITED STATES AND IMPORTS FROM ABROAD

As shown in Table C-1, annual consumption of As_2O_3 in the United States during the 1960's and early 1970's ranged from a low of 20,533 tons in 1963 to a high of 34,585 tons in 1967. Prices during that period did

[1]We understand that such stockpiling also occurs in eastern and western Canada.

TABLE C-1

U. S. CONSUMPTION OF As_2O_3, 1960-1974

Years	Apparent Consumption (short tons)	Average Price[a] ($/short ton)
1960	24,338	77.3
1961	28,328	76.5
1962	25,700	73.4
1963	20,533	75.6
1964	30,663	80.9
1965	31,839	88.1
1966	30,832	86.9
1967	34,585	96.7
1968	31,639	108.1
1969	27,421	116.9
1970	25,863	127.0
1971	23,906	130.1
1972	23,613	135.6
1973	30,496	133.5
1974	32,000	172.1[b]

Notes: a. Average price is based on the weighted average of the domestic price (f.o.b. Tacoma) and the price of imported As_2O_3 (c.i.f.).
b. Estimated.

Source: Asarco, Incorporated, U. S. Bureau of Mines, Minerals Yearbook, various issues, U. S. Foreign Trade, Imports, Commodity by Country.

not fluctuate nearly as much as consumption, but rose steadily from \$77.3/ton in 1960 to \$172.10 in 1974.

Arsenic (i.e., arsenic trioxide, or, in abbreviated form, As) has a wide range of industrial uses in the United States, including the manufacture of pesticides, herbicides, desiccants, glass products, wood preservatives, pharmaceutical preparations, inorganic chemical reagents and nonferrous alloys. Table C-2 shows how the consumption of As has been distributed among these industries since 1968.

Arsenic is primarily consumed by the agricultural chemicals industries for the preparation of arsenical compounds used in herbicides and pesticides. In 1974, the agricultural chemical industry accounted for approximately 67% of the U. S.-consumed As. Arsenic acid (H_3AsO_4) is the most widely-used compound for defoliation of cotton plants. Arsenicals are also used heavily by the cotton industry for weed killing and as a desiccant. Of the agricultural sector, the cotton industry is perhaps the most dependent on arsenicals since no proven substitutes exist.

The glass industry's share of U. S. consumption of As has declined to half what it was in 1968, as reflected in Table C-2. This appears to have been the result of a switch in technology away from using As_2O_3 as a refining agent. The glass industry is continuing to substitute arsenic with cerium oxide in conjunction with selenium for the decolorization of the glass.

The wood preserving industry, according to the U. S. Forest Products Laboratory and the American Wood Preservers Association, have not been able to find an acceptable (primarily odorless) substitute for water-soluble arsenic-based preservatives.

The pharmaceutical industry uses a small portion of As in its formulations.

Arsenic is added to both lead and copper alloys to improve their properties. This market appears to be growing in its relative share of As consumed in the United States. The lead storage battery industry is the primary consumer of As metal. However, development work on a substitute for As in the battery industry has resulted in a calcium alloy substitute. It is still too early to define the extent to which this will displace arsenic.

In conclusion, based on the limited information available, it appears that some U. S. As consumers have been striving toward acceptable substitutes for As-based end-use products. The agricultural chemicals and wood preserving industries, however, have not been very successful in finding acceptable substitutes for their As-based products (i.e., their demand for arsenic is fairly inelastic). The largest of these markets (agricultural chemicals) could disappear if regulations governing the use of arsenic change.

TABLE C-2

CONSUMPTION OF As_2O_3 IN THE UNITED STATES
BY MAJOR END-USE INDUSTRIES
(percent of total consumption)

<table>
<tr><th></th><th>1968</th><th>1971</th><th>1974</th></tr>
<tr><td>Agricultural Chemicals
(SIC 2879) (Pesticides)</td><td>77</td><td>70</td><td>67</td></tr>
<tr><td>Glass and Glassware
(SIC 322)</td><td>18</td><td>20</td><td>9</td></tr>
<tr><td>Industrial Inorganic Chemicals
(SIC 2819) (Catalysts-
reagents)</td><td rowspan="2">4</td><td></td><td>16</td></tr>
<tr><td>Nonferrous Alloys
(SIC 333) (Copper-lead)</td><td rowspan="2">10</td><td>6</td></tr>
<tr><td>Medicinal Chemicals
(SIC 2833) (Agricultural)</td><td>1</td><td>2</td></tr>
<tr><td>TOTAL (Percent)</td><td>100</td><td>100</td><td>100</td></tr>
</table>

Source: Asarco, Incorporated (1974); 1968, and 1971 are estimates.

Table C-3 shows trends in apparent U. S. consumption of arsenic and sources of supply over the period 1960-1973. It can be seen from this table that, during this period, the major share of supplies of As_2O_3 has historically come from abroad. Sweden, the world's largest producer of As is also the largest U. S. foreign supplier at present. Mexico has also been a major U. S. supplier in the past. More recently, domestic sources of As_2O_3 have been supplying a larger share of the U. S. market. In 1962, approximately 61% of the As_2O_3 consumed in the United States was imported; by 1974, only 44% was imported. Some of the increase in the relative share of domestically-produced As_2O_3 can be explained by changes in the domestic price of As_2O_3 relative to the imported price. As the domestic price of As_2O_3 decreased relative to the imported price, U. S. consumers appear to have moved away from foreign-produced toward domestically-produced As_2O_3.

E. ELASTICITY OF DEMAND FOR ARSENIC IN THE UNITED STATES WITH RESPECT TO DOMESTIC AND FOREIGN PRICES

Available analytical evidence suggests the following demand characteristics for arsenic:

- Total arsenic demand is relatively insensitive to price (i.e., inelastic) indicating that U. S. consumers of arsenic have few nonarsenic substitutes available.

- The demand for domestically-produced arsenic is price elastic (i.e., sensitive to both the domestic and import prices of arsenic). Therefore, if domestic prices should rise relative to foreign prices, arsenic users would substitute foreign sources of arsenic for domestically-produced arsenic.

- The demand for arsenic has been more sensitive to domestic and foreign prices in the past in situations when there was excess supply.

Table C-4 shows the shift in the source of As consumed in the United States and the changes in relative prices of domestic versus imported arsenic. In looking at these trends over time (1962-1974), we can see a very definite relationship between the source mix (i.e., domestic vs. imported) and the relative prices. Expressing this relationship in mathematical form and performing the necessary calculations, using historical data, we find that:

Domestic share = 40.8 - 43.1 ln (Relative Domestic Price)

where

Domestic share is the percent of total U. S. As consumption that is domestically supplied; and

TABLE C-3

APPARENT U. S. CONSUMPTION OF As_2O_3 AND SOURCES OF SUPPLY, 1960-1974
(in short tons, unless otherwise indicated)

				Sales of		Prices ($/ton)[a]	
Years	Apparent Consumption	Domestic Production	Stocks	Domestically Produced As	Imported As	Domestic	Imports
1960	24,338	N.A.	3,227	11,913	12,825	72	82
1961	28,328	12,366	6,748	8,845	19,483	82	73
1962	25,700	9,528	3,156	9,942	15,758	82	68
1963	20,533	8,819	6,000	5,974	14,559	82	73
1964	30,663	8,478	2,000	12,478	18,185	88	76
1965	31,839	15,814	1,500	16,314	15,525	94	82
1966	30,832	12,157	1,500	12.157	18,675	99	79
1967	34,585	6,510	500	7,510	27,075	114	92
1968	31,639	8,944	3,000	6,444	25,195	124	104
1969	27,421	13,335	8,400	8,000	19,421	124	114
1970	25,863	14,131	15,500	7,100	18,763	124	111
1971	23,906	9.797	17,700	7,500	16,406	124	133
1972	23,613	13,319	21,000	10,000	13,613	124	144
1973	30,496	13,118	15,000	19,000	11,496	124	149
1974	32,000	9,694	2,500[b]	18,000	14,000	155[b]	194[b]

Notes: a. Average price of As imports both refined and crude; average price of domestically refined As_2O_3.
b. Estimates.

Sources: Asarco, Incorporated, U. S. Bureau of Mines, Minerals Yearbook, various issues.

TABLE C-4

TACOMA'S SHARE OF THE DOMESTIC MARKET AND RELATIVE PRICES OF As_2O_3, 1960-1974

Years	Tacoma's share of the Domestic Market[c] (%)	Domestic Price Relative to Foreign Price[d]
1960	47.3	.87[a]
1961	31.2	1.12[a]
1962	38.7	1.21
1963	29.1	1.12
1964	40.7	1.16
1965	51.2	1.15
1966	39.4	1.25
1967	21.7	1.57
1968	20.4	1.19
1969	29.2	1.09
1970	27.4	1.12
1971	31.4	.93
1972	42.3	.86
1973	62.3	.83
1974	56.2[b]	.75[b]

Notes:
a. Possible noise in the series.
b. Estimated.
c. Domestic share is the percent of total U. S. As consumed that is domestically supplied.
d. Domestic relative price is the domestic price of refined As_2O_3 f.o.b. Tacoma divided by the average imported price of As c.i.f. imported. Most of the imported As is refined As_2O_3.

Source: Asarco, Incorporated, U. S. Bureau of Mines, Minerals Yearbook, various issues.

Relative domestic price is price of domestic refined arsenic f.o.b. Tacoma divided by average c.i.f. imported price.

This equation indicates that, provided world supplies of As are available (i.e., no shortages), U. S. consumers are responsive to relative prices for As. Therefore, a domestic producer of As could expect to lose some of his market share if domestically-produced As prices become much higher relative to the imported prices.[1]

F. CONCLUSIONS

The world arsenic market is highly concentrated on the sellers' side and the demand for arsenic in most uses appears fairly price inelastic[2], at least in the short run. It might be inferred from this that Tacoma, enjoying substantial market power, could increase domestic arsenic prices substantially to alleviate, in part, the burden of pollution control costs associated with any of the options being considered. Our analysis shows, however, that Tacoma will have little to gain by increasing the price of arsenic, if this leads to a rise in relative prices (i.e., domestic price versus foreign prices), particularly in the fact of the present and foreseen world arsenic supply-abundance in the form of stockpiled flue dusts.

---

[1]We believe such a conclusion is strongly indicated even though we realize certain limitations inherent in such an analysis (e.g., relatively small sample; possible errors in the price and quantity data used; the identification problem, that is, the supply schedule and the demand schedule for arsenic interact simultaneously to determine the quantity of domestic arsenic sold and its price).

[2]This is true especially in the case of agricultural chemicals, the most important user of arsenic trioxide. Should the use of arsenic in herbicides, pesticides, etc., be banned or severely curtailed in the future, such a statement about demand elasticity would have much less validity.

APPENDIX D

LEPANTO CONSOLIDATED MINING COMPANY

A. INTRODUCTION

We have made an estimate of Lepanto's copper production cost based on information in their 1975 Annual Report. We attempted to perform the same kind of analysis as was used for Duval (see Appendix G). However, we did not have as much information available. The estimates developed are subject to change if and when more data become available.

B. BACKGROUND

Lepanto produced 43,844 dry metric tons (DMT) of concentrate in 1975, containing 13.3 million kg of copper (about 14,600 short tons). In 1975, 46,448 DMT of concentrate were loaded in four ships: 38,037 tons were sent to Asarco's Tacoma smelter and 8,411 tons to Anaconda in Montana. The concentrate sent to Tacoma contained 1,288 kg of gold and 6,429 kg of silver. That sent to Anaconda contained 171 kg gold and 1,345 kg silver.[1]

Copper production in 1975 declined 11.7% from 1974. Production cutbacks were continued to avoid further inventory accumulation (stocks left on hand at year-end were nearly equal to the amount produced during the year), and were also related to the situation at Asarco, as Lepanto's president stated in the Letter to Stockholders. Indeed, we believe his remarks provide extremely valuable perspective on the situation at Tacoma as far as Lepanto is concerned, and thus reproduce them below:

> "TO OUR STOCKHOLDERS: For the first time since our company resumed mining operations after World War II, a consolidated loss of ₱ 1,746,119 was incurred in 1975 compared to a net income of ₱ 91,734,095 in 1974. Although the Lepanto Mines Division actually lost ₱ 5,517,789, this was partially offset by our subsidiaries which collectively earned a total of ₱ 9,548,069 before income tax. After income taxes and after deducting the shares of minority stockholders in these subsidiaries, they still made a net contribution of ₱ 3,771,670 to the Company, thus bringing our net loss to only ₱ 1.75 million.

The very disappointing loss in our principal division, the Lepanto mines, was brought about by a combination of factors: the low price of copper, averaging US$1.176 per kilogram during the year (US$1.673 in 1974), and the continued decline in gold prices, which averaged US$5.046 per gram during 1975 (US$5.374 in 1974). Accompanying these low prices were steadily increasing operating costs that saw the cost of supplies, tires, fuel, and spare parts rise to record new heights. Likewise, manpower costs and overhead continued to increase.

Moreover, production during the year declined principally because of the lower grade ore that were mined. In spite of our reduced volume of concentrate production (43,844 DMT for 1975 versus 49,630 DMT for 1974), we were not able to reduce our inventory of concentrates to any large extent. We ended the year with 58,023 DMT of concentrate inventory compared to 58,339 DMT the year before.

As reported last year, many of our problems were associated with Asarco's own problems in its Tacoma smelter. Due to pollution regulations in the U. S., Asarco stopped smelting for us during the last three months of 1975 in order to use up their own priced inventory prior to the expiration of their variance permit on January 31, 1976. However, they resumed smelting for us in January and, at the time of this writing, they continue to do so.

In view of the mounting stockpile of concentrates on hand together with the uncertainty at the time of Asarco's continued operation after January 31, 1976 (when Asarco's permit to operate was scheduled to expire) the Company decided late last year to suspend mining operations at the Lepanto Mines Division. We therefore implemented a special leave period under which employees at the mine site were sent on vacation leave with pay from December 10, 1975 to January 15, 1976. During this standstill period, studies were made which prompted the Company to continue indefinitely the suspension of mining operations starting January 16, 1976.

As a result, 1,500 employees have been laid off out of a total of 2,200. The suspension of mining operations and the laying off of employees were cleared with the government agencies concerned. The laid off employees were paid their termination pay and all their unused vacation and sick leaves, and were given financial assistance for an extra period of 60 days from January 16, 1976. They were also given free transportation services, plus a cash relocation allowance. The Company has also committed, on the resumption of mining operations, to give to the laid off employees first preference for reemployment; provided, of course, that the laid off employees meet the requirements of the jobs in question.

The remaining 700 employees have been retained to do essential mine development and rehabilitation, security, care, and maintenance work. This would place the mine in a position to operate more efficiently when we resume operations. Should the prices of copper and gold rise to a point where we would be able to operate profitably, we shall immediately resume production at the Lepanto mines. In the meantime, we intend to continue shipping our concentrates to Asarco's Tacoma smelter until our inventory on hand is used up.

The Puget Sound Air Pollution Control Agency recently held hearings on whether or not to allow Asarco's Tacoma smelter to continue operating under certain conditions. We have been advised by Asarco that the Puget Sound Air Pollution Control Agency has granted its request for a five-year variance to operate its Tacoma smelter.

As we have stated often in the past, we believe that the long term solution to this problem is for the Philippines to have a smelter that is designed to smelt Lepanto's material together with other Philippine copper concentrates. We are pleased to report progress on this project during the past year. With three other mining companies, Lepanto has brought this project to a decisive stage whereby the basic engineering activities have been accomplished and contract proposals with firm prices of equipment have been received. In view of the necessity of state assistance, we have turned over to the President's Copper Smelter Advisory Committee headed by Secretary Vicente T. Paterno, the leadership in pursuing this project to a successful conclusion. We are confident that decisive action will be taken soon by our Government so that we can get this long delayed project onstream. ...

... Since the price of copper is such an important factor in our decision on whether or not to reopen our mine, we hesitate to forecast how we will fare in 1976. At present it appears to us that, although there are signs of an economic upturn in the U.S., such signs are still not an assurance of a sustained increase in the price of copper. The continuing imbalance in the supply and demand situation, which is highlighted by the large copper inventories in the London Metal Exchange warehouses and in Japan pose a bearish influence on the price. It is our intention to review the situation periodically.

> Anticipating all these, Management has taken steps to drastically cut down all overhead expenses and conserve as much as possible our cash resources in order to meet our financial commitments to the Roaster and Smelter Projects. Our financial consultants, together with Management, are studying the critical problem of raising funds for these priority projects. We can only assure you that all efforts will be devoted to these, so that our Company's long term future can be assured. We have a good and rich mine that, although plagued by arsenic and other impurities, is still a very viable one under normal conditions. ..."

Exhibit D-1 presents a 10-year picture of the mining operations. Note the departure in 1974-1975 in the ore grade, mined down to 1.78% copper, compared to the consistently higher grade of the prior years. We believe this was a logical consequence of the sharp increase in copper and gold prices in 1974. The January 1, 1976 ore reserves reported by Lepanto had an average grade of 2.6%, which is similar to the average grade of ore mined over the period 1966-1973. Estimated remaining economic ore reserves amounted to 7.56 million tons containing about 218,000 tons of copper and 29,000 kg gold.

C. PHILIPPINES COPPER SMELTER PROJECT[2]

According to the 1975 Annual Report, in 1975 Lepanto Consolidated Mining Company and three other copper mining companies in the Philippines organized the Copper Smelter Corporation of the Philippines (CSCP) to set up a copper smelting and refinery project. Several officers of Lepanto are among the key officers of the CSCP.

"The project involves the setting up of a smelter and refinery in Negros Occidental capable of producing 84,000 metric tons per year of cathode copper for the local and export markets. The well known and proven flash smelting process developed by Outokumpu Oy of Finland shall be employed in treating concentrates from the different Philippine copper mines.

The refinery shall be designed to turn out cathode copper which meets international standards and special high purity consumer standards. CSCP is currently making arrangements with Philipp Brothers Oceanic of the U.S. and Marubeni Corporation of Japan for the marketing of the smelter's products abroad. In a memorandum of agreement executed with CSCP, Planters Products, Inc. has agreed in principle to purchase the smelter's byproducts of sulphuric acid for the production of fertilizer in its plant to be built next to the copper smelter. Gold and silver separated from copper will be refined in a precious metals plant within the smelter complex capable of treating additional gold and silver from other Philippine producers. Selenium and bismuth recovered from the smelter will be sold to specialist refiners abroad.

TABLE G-2

DUVAL COPPER MINING AND MILLING

Property and Year	Ore Milled (Thousands of Tons)	Mineral Content		Gross Revenues Per Ton Sold[2]	Costs Per Ton Sold[3,4]
		Copper	Molybdenum		
Esperanza[1]					
1971	-	-	-	-	$3.32
1972		Suspended Operations			
1973	6,006	0.34%	0.039%	$4.47	3.46
1974	6,628	0.31	0.039	5.89	4.51
1975	5,341	0.26	0.041	4.33	4.02
1976	5,409	0.29	0.037	7.39	6.48
Mineral Park[1]					
1971	-	-	-	-	3.65
1972	6,976	0.41	0.036	3.88	2.81
1973	6,648	0.38	0.042	5.46	3.66
1974	6,247	0.36	0.040	5.29	3.81
1975	5,620	0.30	0.043	4.28	4.13
1976	4,743	0.28	0.048	4.57	5.01
Battle Mountain[1]					
1971	-	-	-	-	5.50
1972	1,625	0.84	-	6.72	5.66
1973	1,781	0.63	-	5.67	5.38
1974	1,730	0.55	-	7.72	7.67
1975	1,690	0.66	-	9.36	8.72
1976	1,716	0.71	-	13.20	11.63
Sierrita[1]					
1971	-	-	-	-	2.67
1972	28,304	0.29	0.029	3.01	2.65
1973	29,885	0.28	0.031	3.94	3.01
1974	30,885	0.29	0.026	4.66	3.81
1975	31,387	0.33	0.030	3.84	3.97
1976	32,968	0.35	0.035	6.75	5.14

[1]Design milling capacities at Esperanza, Mineral Park and Battle Mountain (near the Copper Canyon mine) are 15,000, 19,000 and 4,000 tons of ore per day, respectively. From the commencement of mining operations at the Battle Mountain mines through December, 1976, the Copper Canyon mine has accounted for approximately 82% of the tonnage milled at Battle Mountain, Design throughput at Sierrita is 82,500 tons of ore per day.

[2]Excludes revenues from leach-precipitation operations.

[3]Includes the cost of mining leach material (except for Battle Mountain and Sierrita) and all mining, milling, smelting, refining and indirect operating costs, but excludes depreciation, depletion and interest. The average per ton depreciation and depletion for mill and leach copper allocable to tons milled and sold was as follows:

Property	1972	1973	1974	1975	1976
Esperanza	$ -	$ .18	$ .19	$ .16	$ .13
Mineral Park	.29	.31	.20	.19	.13
Battle Mountain	.68	.64	.68	1.19	1.83
Sierrita	.28	.31	.33	.34	.38

[4]The weighted average rate of escalation in unit mining costs was 13.3%/year.

Complete process and design engineering studies for the project have been completed and contract proposals received. The project, which involves an investment of approximately US$250 million, is expected to be operational in late 1978 or early 1979.

The establishment of the copper smelter and refinery will minimize the current dependence of Lepanto and other mining companies on foreign smelters and encourage the local and regional development of related industries like the wire and cable and copper fabrication industries. The sales of precious meatls, savings of mining companies from the nonincurrence of shipping costs to and smelting charges of foreign smelters, and the reduction of sulphuric acid importations are expected to result in net foreign exchange earnings and savings of approximately US$25.1 million annually."

D. ROASTER PROJECT

The Lepanto Roaster Project involves the setting up of a roasting plant to remove the arsenic and antimony from Lepanto's concentrates prior to smelting. The plant, which is designed to be integrated with CSCP's smelter, will be built adjacent to the smelter complex. The establishment of the roaster plant will commence as soon as decisions on the copper smelter are finalized.

E. CURRENT COPPER COST STRUCTURE

Because Lepanto showed a loss on copper sales in 1975, we can estimate and reconstruct the sales which would show a break-even on a Lepanto accounting basis. In the following calculations, we translated at the average rate of $0.1343 per peso, as implied in the Lepanto Annual Report.

Let AVC´ = out of pocket Lepanto costs excluding interest charges.

Then,

AVC´ = [(Loss) + Sales Revenues] - Depreciation - Interest 1975

Sales of 27.6 million pounds of copper were $14.8 million; sales of gold and silver $8.5 million (equal to $0.31 per pound of copper sold). Break-even revenue was the sum of the loss or $0.75 million and total 1975 sales of Lepanto Mines Division of $23.3 million.

Based on the 1975 Annual Report, we estimated related depreciation and depletion charges of about $6.4 million; and interest of about $0.6 million. This gave an AVC´ of $0.62/lb, including smelting, refining, and transportation charges (SR&T).

Check:	Break-even sales	$24.1 MM
Less:	Cost of Goods Sold ($\frac{\$0.62}{1b}$ x 27.6 MMlbs)	-17.1
	Depreciation and Interest	- 7.0
	Net profit	0.0

Subtracting an estimated 22¢/lb for SR&T, we have:

$AVC \cong AVC' - \$0.22 = \$0.40$

We have to adjust the 1975 estimate to reflect the reduced operating rate and ore grade, as compared to "normal" conditions. We assumed unit costs for 1975 would be reduced under normal operations in proportion to the 0.7 power rule of thumb,

$$AVC_{1975} \approx \overline{AVC}_{1975} \left(\frac{P}{P_{1976}}\right)^{(1-0.7)}$$

where the bar denotes normal capacity operations of about 2.0 times the copper production of 1975 (see Exhibit D-1).

We also adjusted for the extraordinarily higher out-of-pocket expense due to the shutdown pay given the workers laid off in December. We estimated this to have increased the 1975 AVC of $0.62/lb by about 8%.

The adjusted AVC was estimated as follows:

$$\overline{AVC}_{1975} \approx \frac{.40 \div 1.08}{(2)^{.3}} \approx \$31/lb$$

The ATC was based on the following capital charges:

	$ per lb copper production
Capital Recovery	
Depreciation and depletion	.12
Cost of Capital Including Incomes Taxes	
Basis: $0.53/lb LME, $1 assets/$ sales	
A. Debt (20% of capital, @10%)	.01
B. Equity (80% of capital, @ 25% pre-tax)	.11
	$ .24/lb

$\overline{ATC}_{1975} = \overline{AVC}_{1975} + 0.24 \approx \$0.55/lb$

$AVC + Interest \approx \$.32/lb$

To estimate in terms of 1978 dollars, one has to assume the effects of Philippine inflation as well as the possible change in the value of the peso vis-á-vis the U. S. dollar. To a first approximation, we assume these are offsetting, so that:

$$\overline{AVC}_{1975} \approx AVC_{1978}$$

$$ATC_{1975} \approx ATC_{1978}$$

In terms of copper prices, one must add in the 1978 Tacoma base case SR&T charges re Lepanto, i.e., approximately 23¢/lb for SR&T.

Then, copper price to yield ATC to Lepanto $\approx$ \$0.55 + 0.23 $\approx$ \$0.78/lb.

REFERENCES

1) 1975 Annual Report to Lepanto Consolidated Mining Company.

2) This description from Lepanto's 1975 Annual Report is dated. See Appendix E for details on the recent development.

APPENDIX E

THE PHILIPPINE SMELTER

The government of the Republic of the Philippines has been interested in a local smelter for many years in order to create additional employment, foster the development of satellite manufacturing industry and reduce the dependence on the Japanese smelters.

The early feasibility studies were done in the late 1960's.[1] Several groups have prepared feasibility studies based on various processes such as flash smelting, pre-roasting, etc. At one time, even the Mitsubishi process was suggested. Several locations have been considered, e.g., Poro (most convenient to the Northern Luzon mines), Negros Occidental (convenient to Marinduque), Cebu (Atlas), Bataan Industrial Park (away from mines but near a power source), and Quezon or Batangas (a location not near any major mine but near Manila). Smelter sizes considered most often have been in the range of 80,000 to 120,000 tons/year. The recent developments are discussed below.

In 1975-early 1976, there were two groups considering smelter projects. The First Smelter Corporation (mainly Lepanto and Marinduque) was considering a $250 million smelter on Negros Occidental.[2] Atlas was considering one initially on Cebu near the mines and then on Bataan, near a source of power. Atlas' proposal was turned down by the Philippine Economic and Development Authority[3] and the plans were subsequently shelved.[4]

In mid-1976, a new company, Philippine Associated Smelting and Refining Corporation, was formed which superceded the First Smelter Corporation.[5,6] The participants were: Atlas Consolidated, Marcopper, Philex, Marinduque, Lepanto, Western Minoloco, Black Mountain, Consolidated Mines, Benguet Consolidated, Acoje Mining and CDCP Mining. The equity participation was in proportion to concentrate production, i.e., the ability to supply the smelter.

The latest information (late 1976-early 1977)[1,7] indicates that Arthur G. McKee will build a smelter and refinery with rod casting facilities in either Batangas or Quezon, near Manila. This facility will produce 84,000 tons/year of copper and is expected to be in operation in 1979-80. The eleven companies will contribute 36% of the equity; the Government, 34%; and foreign interests, 30%. Since Philippine imports of refined copper are about 15,000 tons/year[1], much of the copper output will be exported.[7,8]

REFERENCES

1) Far Eastern Economic Review, November 12, 1976, pp. 68-72

2) a. Metals Week, July 5, 1976
   b. Metals Week, November 2, 1976

3) Metals Week, January 26, 1976

4) Metals Week, April 19, 1976

5) Metals Week, August 30, 1976

6) Engineering and Mining Journal, October 1976

7) a. Metals Week, October 25, 1976
   b. Engineering and Mining Journal, February 1977
   c. Engineering and Mining Journal, December 1976

8) Metals Week, December 20, 1976

APPENDIX F

ASARCO'S NORTHERN PERU MINING CORPORATION

Northern Peru Mining Corporation (NPMC), an Asarco subsidiary, operates the Quiruvilca mine and mill, 450 miles north of Lima, Peru. The ore body is complex and produces silver-rich copper and lead-zinc concentrates. During the period 1971-1975, ore milled was over 300 thousand tons/year with copper content about 2%. Copper production amounted to an average of 7,600 tons/year. In 1976, production shifted to favor lead-zinc-silver production at the expense of copper, which dropped to 3,800 tons.

Peruvian General Mining Law and Regulations provide for the participation by employees of mining companies operating in Peru, through Mining Communities, in the ownership and management of the Peruvian assets of such companies.[1] The law contemplates that employee participations will evenutally amount to 50%. Under the law and regulations (which became effective in the second half of 1971), 10% of earnings, before taxes and depletion, is to be paid over for the eventual benefit of employees of the Peruvian mining industry, with an additional 1% of such earnings to be paid to Peru's Mining, Scientific & Technological Institute. Sixty percent of the payments to be made for the benefit of employees is to be made through the issuance of certificates of participation in net assets which are located in Peru, and forty percent of such payments is to be made in cash.

In addition, the General Mining Law requires that each foreign mining company operating in Peru establish a governing body ("Organo Director") to govern its local activities. The Mining Community must be represented by at least one member on the Organo Director and voting power is allocated between the Mining Community and the mining company in proportion to the participation certificates held by each.

We understand that NPMC has not been a profitable operation. In 1975, Asarco proposed the transfer of its interest in the Quiruvilca mining unit to an appropriate agency of the government at no cost to the Government.[2] (This was at the time when the Peruvian Government had just nationalized the assets of Marcona Mining Corporation, owned by Cyprus Mines and Utah International of the U. S.)

The Peruvian Government did not take over this operation but negotiations with the government and labor officials led to an agreement on reducing the work force by one-third plus other adjustments intended to make the operation profitable.[3]

Our understanding is that the Peruvian Government's marketing entity for mineral products, Minero Peru Commercial (Min Peco) controls all transactions involving Peruvian mineral products including the Northern Peru concentrates. Min Peco negotiates the processing of Quiruvilca's output usually with International Metals, a wholly-owned Asarco subsidiary, and may have it tolled through Tacoma, or sold to Asarco on the basis of a custom smelter contract through Tacoma.

We do not have in our possession either the mining and milling costs at Quiruvilca or the smelting and refining contract governing transactions at Tacoma regarding the mine. Based on the information presented above, we have assumed that Quiruvilca has been and will continue being a marginal operation.

For analytical purposes, Quiruvilca and Lepanto are treated together since they share the following characteristics: high impurity concentrates, marginal mines, and no alternative smelter outlets at this time. It may be assumed that the costs of production at Lepanto and Quiruvilca are similar since Quiruvilca was showing a loss in 1975, and Lepanto shut down in late 1975 and showed a loss that year (during which there was a sharp drop in copper prices.)[4]

Northern Peru Mining Corporation (NPMC) and Southern Peru Copper Corporation (SPCC) are the two largest mining operations not owned by the Peruvian Government.[5] In deciding not to nationalize Northern Peru and in allowing a reduction in the work force, we assume that the Peruvian government resolved to their satisfaction the nature of the transfer costs between NPMC, Tacoma, and Asarco-New York, and presumably decided that high labor costs were the reason for the unprofitable operation of the mine.

In comparison with the much larger SPCC operation, it should be noted that the net assets in Peru of Asarco's wholly-owned subsidiary NPMC amounted to $5.6 million at December 31, 1976, whereas its equity investment in SPCC amounted to $154.6 million.[6]

REFERENCES

1) Pages A-35, A-74 of July 1976 Official Statement issued in connection with Asarco environmental improvement revenue bond financing; also, page C-11 and page C-12 of the 1974 and 1976 Form 10-K reports of Asarco.

2) a. Engineering and Mining Journal, September 1975, page 212.
   b. Simon D. Strauss, Executive Vice President, Asarco, Inc. Testimony before U. S. Department of Labor, OHSA, re: Proposed Standard for Occupational Exposure to Inorganic Arsenic, September 9, 1976, page 464.

3) Metals Week, December 15, 1975.

4) Lepanto Consolidated Mining Company Annual Report, 1975.

5) Simon D. Strauss, loc. cit., page 464.

6) Page 27 of the 1975 Annual Report of Asarco.

APPENDIX G

DUVAL CORPORATION

Duval is a wholly-owned subsidiary of Pennzoil Company. Pennzoil is a large natural resources company engaged in oil and gas exploration, production, refining, and marketing; and the mining and processing of ores and minerals, principally copper, molybdenum, sulfur, and potash. Pennzoil's total revenues in 1976 were $1.02 billion, with net income of $167.6 million. Total employment was approximately 9,500 as of December 31, 1976. Duval accounted for about one-third of Pennzoil's revenues and somewhat more than one-half of its gross operating income. Details on Duval are presented below.[1]

A. COMPONENTS OF REVENUES AND INCOME

The data in Table G-1 indicate the components of Duval's mining business and sources of gross income (before total interest charges, Federal income tax, and unallocated general corporate overhead expense).

B. METALS

Duval owns and operates three open-pit copper-molybdenum mines in Arizona and two open-pit copper mines in Nevada. Silver is recovered as a byproduct from all the ore bodies, and gold is recovered as a byproduct from the Nevada ore bodies. Duval's largest mine, the Sierrita Property located near Tucson, Arizona, is owned by Duval Sierrita Corporation (Duval Sierrita), a wholly-owned subsidiary of Duval. Operations at the Sierrita Property began in 1971. Duval's Esperanza Property, which is adjacent to Sierrita, has been in production since 1959, while Duval's Mineral Park Property, located near Kingman, Arizona, has been in production since 1964. The Nevada mines, Copper Canyon and Copper Basin, are located near Battle Mountain, Nevada and have been in production since 1967.

Duval owns and operates a total of four concentrating mills located at or near each of its mines for the conversion of ore into copper or molybdenum concentrates. Average concentrator recovery has been 84.80% of the copper assay content of all ore milled. Copper is also produced from supplemental leach-precipitation operations at the mines (except Sierrita). Such operations entail the leaching of waste rock with an acidic solution and the treatment of the resulting copper-bearing solution in a precipitation plant to produce copper precipitates.

Duval's copper concentrates and precipitates are currently sold as such or are toll smelted and refined by others for redelivery to and marketing by Duval. Duval has recently completed the physical construction of and is

TABLE G-1

DUVAL LINES OF BUSINESS

	1974	1975	1976
Production (Thous. Tons)			
Metals			
Copper	133	138	145
Molybdenum	9	10	12
Sulfur (long tons)	2,352	2,174	1,771
Potash			
U. S.	520	504	441
Canadian*	962	778	612
Sales (Thous. Tons)			
Metals			
Copper	122	157	101
Molybdenum	10	8	11
Sulfur	1,993	1,787	1,925
Revenues ($ Millions)			
Metals	185	159	187
Other	96	125	142
Total	281	284	329
Gross Operating Income ($ Millions)			
Metals	33	(13)	32.6
Other	37	50	63.4
Total	70	37	96.0

*Disposed of in October 1976.

now in the process of starting up the operation of a CLEAR-process hydrometallurgical plant near the Sierrita Property for the electrolytic production of copper crystals (equivalent to a high-grade blister copper) from concentrates produced at the Esperanza and Sierrita Properties and precipitates produced at the Esperanza and Mineral Park Properties. The patented CLEAR process is designed to create no solid, liquid or gaseous pollution. The plant is designed to produce 40,000 tons of copper crystals per year. It is currently estimated that the plant will cost a total of $51,000,000, including capitalized interest and start-up and test costs. The copper crystals will be sold as such to conventional electrolytic copper refiners and (to a limited extent) to fabricators or will be toll-refined by others for marketing by Duval.

Most of Duval's molybdenum concentrates are currently treated by Duval for marketing as molybdenum sulfide or for roasting in Duval's roasters. The roasted product, molybdenum trioxide, is packaged and marketed by Duval as technical molybdic oxide. The balance of the molybdenum concentrates is converted into ferro-molybdenum, one of a broad line of products offered to the steel and foundry industries. In 1975, Duval completed the construction of new facilities, adjacent to the Esperanza Property, for the production of ferro-molybdenum in the domestic market. This plant is designed to produce 3,500,000 pounds of ferro-molybdenum annually, and currently processes approximately 45% of that portion of Duval's molybdenum concentrates converted into ferro-molybdenum. The conversion of the remainder of the molybdenum concentrates into ferro-molybdenum is currently done for Duval by others on a toll basis for sale in the European market.

C. RESERVES

The following table sets forth reserve information concerning the metals operations at Duval:

	Reserves[1]				
		Average Mineral Content			
Property	Ore (Thousands of Tons)	Copper	Molybdenum	Gold (Ounces Per Ton)	Silver (Ounces Per Ton)
Esperanza	25,779	0.42%	0.022%	-	-
Mineral Park	55,502	0.29%	0.038%	-	-
Battle Mountain:					
Copper Canyon	6,144	0.52%	-	0.034	0.37
Copper Basin	821	1.04%	-	0.025	0.25
Sierrita	489,577[2]	0.32%	0.033%	-	-

[1]As of December 31, 1976, as estimated by Duval.

[2]The stripping ratio during the operational life of the mine, excluding pre-mining stripping of waste overburden, is estimated to be 0.93 to 1, while the stripping ratio during the first five years of operations was approximately 1.72 to 1.

D. SMELTING, REFINING, MARKETING

Duval's copper production accounts for approximately 8-10% of domestic mine copper production. Substantially all Duval's copper sales recently have been made in the U. S.

Asarco currently smelts and refines substantially all Duval's copper concentrates and precipitates. Under existing arrangements, Asarco purchases a portion of the copper production (in the form of copper concentrates and precipitates) and smelts and refines the balance on a toll basis for redelivery to and marketing by Duval. Duval's current sales are made to a number of wire and brass mills. During 1976, approximately 52% of Duval's total copper production was toll-smelted by Asarco; 25% was purchased by Asarco; 11% was processed in the start-up operations of Duval's CLEAR plant; 7% was sold to other refiners; and 5% was added to inventory.

At December 31, 1971, Duval suspended its mining and milling operations at Esperanza until January 16, 1973, as a result of an Asarco work stoppage. In 1975, because of an accumulation of concentrate inventory resulting from an Asarco work stoppage in 1974 and decreases in demand for copper, operations at Esperanza and Mineral Park were curtailed from a seven-day week to a five-day week. The curtailment resulted in approximately a 17% reduction in the rate of Duval's total copper production until September 1976, when both properties resumed a seven-day week.

The copper-bearing material from Duval's Battle Mountain mines are handled by Asarco's Tacoma operation. The material from the other Duval mines is handled by all of the Asarco smelters.

The contractual arrangements governing the processing of Duval's copper-bearing materials by Asarco are, we believe, presently being renegotiated by Duval and Asarco. Our understanding is that both parties seek an omnibus contract covering a stated amount of concentrates per year company-wide. Apparently, no agreement has yet been reached. We were not and are not privy to any details.

Duval and Duval Sierrita are limited partners in a partnership formed by Asarco which has constructed and is now operating pollution control facilities at Asarco's Tacoma, Washington and El Paso, Texas smelters. While the planned facilities are expected to reduce the emission of sulfur oxides at the plants by approximately 50%, Duval has been advised by Asarco that substantially greater emission controls may be imposed upon Asarco's smelters at any time.

Effective January 1, 1976, Duval declared its own price basis for its refined copper. Previously, Duval copper was priced on the basis of the <u>Metals Week</u> wirebar average for U. S. producers, delivered. As of July 1, 1977, the quoted U. S. producer price was 68¢/lb, back to where it was in February. Pennzoil stated in its 1976 Form 10-K report, that if construction, automobile production, and capital expenditures continue at

February, 1977 levels, it is expected that the market for copper will continue to be adversely affected.

Duval competes with a number of companies in sales of molybdenum products. The quoted domestic price per pound to the steel industry for molybdic oxide has increased from $1.65 in August, 1973 to $2.90 at March 1, 1976, and $3.82 at February 1, 1977.

E. DUVAL SIERRITA[2]

In November, 1967, the United States Government through the General Services Administration (GSA) and Duval Sierrita Corporation, an operating subsidiary of Duval, entered into a domestic copper production expansion contract pursuant to the provisions of the Defense Production Act of 1950 for the development of a low-grade copper-molybdenum ore body (Sierrita Property) adjacent to Duval's Esperanza Property. Construction of a mill and related facilities was substantially completed in March, 1970. Approximately $181 million was required to develop the original project (not including the cost of the expansion project referred to below) of which $83 million was obtained from the GSA in the form of advances against future deliveries of copper produced from the property; $48.75 million from commercial bank loans guaranteed in part by the GSA; $10 million from Pennzoil; and the remainder from Duval in equity or loans.

The contract with the GSA provided for repayment of advances by delivery of about 218.4 million pounds of copper to the GSA prior to June 30, 1975, the advances credited at the rate of 38¢ for each pound of refined copper delivered. While the contract provided that certain minimum deliveries be made, Duval Sierrita was entitled to sell in the open market its molybdenum and byproduct silver production and such amount of its copper production as may be necessary to cover all cash operating expenses and maintain working capital. Asarco entered into a ten-year Hayden smelting agreement with Duval Sierrita, and also agreed to purchase 50% of the non-GSA concentrate production.

In May, 1970, these contracts were amended to provide for an increase in the mine and mill capacity at the Sierrita Property. Duval Sierrita agreed to spend not less than $8 million on additional facilities of about $13 million and guaranteed the GSA an average rate of ore throughput on an annual basis of not less than 72,000 tons per day. In turn, the GSA and the commercial banks agreed to permit Duval Sierrita to sell on the open market for its own account 90% of production attributable to any ore throughput exceeding 72,000 tons/day. The remaining 10% of such production (net of sales required to meet cash operating expenses attributable thereto) were to be delivered to the GSA at a fixed price of 38¢/lb.

Start-up operations commenced in the first quarter of 1970. The facilities for integrated copper-molybdenum milling operations were not completed until the latter part of 1970, and normal production did not commence until 1971. Sierrita produces "clean" concentrate.

In 1975, Duval arranged for a new \$55 million bank credit for substantial acceleration of deliveries to the GSA. The negative contribution of metals operations in 1975 (see Table G-1) reflects the acceleration of copper deliveries (65,000 tons), principally in November and December, 1975, to discharge at 38¢/lb the balance due the GSA, and overall lower prices for copper. In November, 1976, all other indebtedness incurred in the development of Duval's Sierrita Property was discharged.

F. PRODUCTION COSTS

Tables G-2 and G-3 present information on Duval's costs associated with copper mining and milling operations. It may be seen from Table G-2, for example, that in 1975, gross margin per ton of Battle Mountain concentrate, excluding leach-precipitation operations revenues, was equivalent to 4.8¢/lb contained copper produced. This was before any capital charges and depletion cost; depreciation and depletion charges alone exceed this margin, so that Battle Mountain shows no earnings for 1975. Substantially the same result obtained for 1976, with copper prices averaging under 70¢ during the period.

Battle Mountain's costs have been increasing about 15%/year. We calculated the weighted average cost of 1976 production, including leach-precipitate operations, to be 68¢/lb copper produced, before byproduct credits, and before any depreciation, depletion, interest, profit or taxes. (For 1975, we calculated this to be approximately 60¢/lb on the same basis.) Battle Mountain ore has a good gold and silver content, and we estimate it produces roughly \$7.5 million/year in credits, or roughly 30% of Battle Mountain's revenues, at current precious metal prices. (This is equivalent to a byproduct credit of about 22¢/lb of copper recovered.) Subtracting estimated Tacoma charges and freight costs, we estimated the 1976 average variable costs (AVC) for Battle Mountain concentrate to be about 46¢/lb copper, or 24¢ equivalent with credit for gold and silver at 1976 prices.

In 1978 dollars, using the five-year cost history for Battle Mountain, we estimate AVC to be about \$0.60/lb, or \$0.38/lb net of gold and silver credits.

G. OVERALL DUVAL MINING COST FOR COPPER

Knowing the production, sales, and profit figures overall for Duval's metal mining operations, as shown in Table G-1, we can estimate the copper price required to meet average variable costs (AVC) and average total costs (ATC). We write two simultaneous equations with two unknowns, the effective cost of producing copper (Cu), and the cost of producing molybdenum (Mo).

Let Q^{Cu}, Q^{Mo} - denote quantity sold, millions of pounds, Cu or Mo

P_c - denote Duval's net overall cost in \$/lb, including depreciation, smelting, refining, transportation, but before interest, profit, and income taxes

TABLE G-2

DUVAL COPPER MINING AND MILLING

Property and Year	Ore Milled (Thousands of Tons)	Mineral Content Copper	Molybdenum	Gross Revenues Per Ton Sold[2]	Costs Per Ton Sold[3,4]
Esperanza[1]					
1971	-	-	-	-	$3.32
1972		Suspended Operations			
1973	6,006	0.34%	0.039%	$4.47	3.46
1974	6,628	0.31	0.039	5.89	4.51
1975	5,341	0.26	0.041	4.33	4.02
1976	5,409	0.29	0.037	7.39	6.48
Mineral Park[1]					
1971	-	-	-	-	3.65
1972	6,976	0.41	0.036	3.88	2.81
1973	6,648	0.38	0.042	5.46	3.66
1974	6,247	0.36	0.040	5.29	3.81
1975	5,620	0.30	0.043	4.28	4.13
1976	4,743	0.28	0.048	4.57	5.01
Battle Mountain[1]					
1971	-	-	-	-	5.50
1972	1,625	0.84	-	6.72	5.66
1973	1,781	0.63	-	5.67	5.38
1974	1,730	0.55	-	7.72	7.67
1975	1,690	0.66	-	9.36	8.72
1976	1,716	0.71	-	13.20	11.63
Sierrita[1]					
1971	-	-	-	-	2.67
1972	28,304	0.29	0.029	3.01	2.65
1973	29,885	0.28	0.031	3.94	3.01
1974	30,885	0.29	0.026	4.66	3.81
1975	31,387	0.33	0.030	3.84	3.97
1976	32,968	0.35	0.035	6.75	5.14

[1]Design milling capacities at Esperanza, Mineral Park and Battle Mountain (near the Copper Canyon mine) are 15,000, 19,000 and 4,000 tons of ore per day, respectively. From the commencement of mining operations at the Battle Mountain mines through December, 1976, the Copper Canyon mine has accounted for approximately 82% of the tonnage milled at Battle Mountain, Design throughput at Sierrita is 82,500 tons of ore per day.

[2]Excludes revenues from leach-precipitation operations.

[3]Includes the cost of mining leach material (except for Battle Mountain and Sierrita) and all mining, milling, smelting, refining and indirect operating costs, but excludes depreciation, depletion and interest. The average per ton depreciation and depletion for mill and leach copper allocable to tons milled and sold was as follows:

Property	1972	1973	1974	1975	1976
Esperanza	$ -	$ .18	$ .19	$ .16	$ .13
Mineral Park	.29	.31	.20	.19	.13
Battle Mountain	.68	.64	.68	1.19	1.83
Sierrita	.28	.31	.33	.34	.38

[4]The weighted average rate of escalation in unit mining costs was 13.3%/year.

TABLE G-3

DUVAL LEACH-PRECIPITATION OPERATIONS

Property and Year	Pounds of Copper Produced[1]	Gross Revenues from Precipitates	Leach-precipitation Operating Costs[2]
	(Expressed in thousands)		
Esperanza			
1972	2,094	$ 1,153	$ 529
1973	995	550	346
1974	1,817	290	219
1975	3,960	521	758
1976	6,412	1,607	2,030
Mineral Park			
1972	8,936	5,319	2,281
1973	6,431	4,011	1,799
1974	6,801	5,028	2,801
1975	6,915	3,294	2,205
1976	6,817	2,803	2,793
Battle Mountain			
1972	13,660	7,648	3,258
1973	12,762	7,344	2,946
1974	14,410	11,890	4,870
1975	11,468	7,740	5,220
1976	9,902	6,600	3,855

[1] Leach-precipitation operations at the Esperanza, Mineral Park and Battle Mountain Properties accounted for 28%, 18%, 22%, 24% and 26% of total copper production from these properties during the years 1972, 1973, 1974, 1975 and 1976, respectively.

[2] Operating costs include smelting and refining costs, but exclude mining costs of leach material (except for Battle Mountain) and depreciation of the leach-precipitation plants. Depreciation of the leach-precipitation plants in thousands of dollars was as follows:

Property	1972	1973	1974	1975	1976
Esperanza	$ 5	$ 5	$ 44	$ 46	$ 45
Mineral Park	68	78	78	88	107
Battle Mountain	78	84	89	89	89

P_c^{Cu} - denote P_c for copper, \$/lb

P_c^{Mo} - denote P_c for molybdenum, \$/lb

P^{Cu}, P^{Mo} - denote estimated average price received for contained copper and molybdenum, respectively, \$/lb, including byproduct credits.

Then, for <u>1975</u>, we have (in millions):

Revenues - Costs = Margin before interest and taxes

$$Q^{Mo}(P^{Mo} - P_c^{Mo}) + Q^{Cu}\left[\left(\frac{\$159 - Q^{Mo}P^{Mo}}{Q^{Cu}}\right) - P_c^{Cu}\right] = -\$13$$

$$16 \times \$2.50 - 16\ P_c^{Mo} + \$119 - 313\ P_c^{Cu} = -\$13$$

$$P_{c,75}^{Cu} = 0.55 - 0.05\ P_{c,75}^{Mo}$$

For <u>1976</u>, similarly:

$$22\ (\$3.00 - P_c^{Mo}) + \$121 - 202\ P_c^{Cu} = \$32.6$$

$$P_{c,76}^{Cu} = 0.77 - 0.11\ P_{c,76}^{Mo}$$

From the Pennzoil 10-K data, we assumed:

$$P_c^{76} \simeq 1.20\ P_c^{75}$$

Then

$$1.20\ P_{c,75}^{Cu} \simeq 0.77 - 0.11 \times 1.20\ P_{c,75}^{Mo} \qquad (1)$$

$$P_{c,75}^{Cu} \simeq 0.55 - 0.05\ P_{c,75}^{Mo} \qquad (2)$$

Solving,

$$P_{c,75}^{Cu} = \frac{0.77}{1.20} - 0.11\left[11 - 20\ P_{c,75}^{Cu}\right]$$

$$P_{c,75}^{Cu} \simeq 0.474$$

and $P_{c,76}^{Cu} \simeq 0.569$ or 57¢/lb (including the effective credit for by-products)

We estimated the equivalent overall AVC as 29¢/lb, by deducting 28¢/lb of estimated smelting, refining, transportation, and depreciation charges (and reflecting approximately 4¢/lb credit overall for gold and silver).

In 1978 dollars, we assumed escalation at the five-year weighted average rate of total production costs, 13.3% per year including inflation and productivity effects. Thus, the 1978 estimated AVC for copper concentrate is ∿38¢/lb at Duval.

To get ATC, we added estimated fixed costs and allowance for return on investment and taxes, as follows:

Capital Recovery

Depreciation and cost depletion: ∿6¢/lb based on 10-K data

Cost of Capital

Interest: ∿2¢/lb (out of pocket)

Return on equity and tax: ∿9¢/lb

Total capital charges: ∿17¢/lb

The cost of capital estimate is based on an assumed $1 of investment per $1 metal mining revenue (which gives reasonable agreement with the data) and 40% debt at 7%, 60% equity at 23% pre-tax (as indicated by Pennzoil financial statistics).

The 1978 Duval estimated ATC at the mining level is thus ∿55¢/lb.

REFERENCES

1) Information from Pennzoil Company's Form 10-K report filed with the Securities and Exchange Commission for the year ended December 31, 1976, pp. 9-16.

2) Information from Pennzoil-United's March 23, 1971 prospectus and Pennzoil Company's 1976 Form 10-K report.

APPENDIX H

ORDER-OF-MAGNITUDE COSTS OF A NEW SMELTER AND REFINERY

Tables H-1 and H-2 present order-of-magnitude costs for a flash smelter and a conventional electrolytic refinery. These costs are for illustrative purposes only and suggest that the costs for such facilities are in the range of 33-35¢/lb.

TABLE H-1

ORDER-OF-MAGNITUDE OPERATING COSTS FOR A FLASH SMELTER

	Unit	$/Unit	Units/ Ton Cu	$/Ton Cu
A. Capital Investment (CI)			$1,000/annual ton	
B. Operating Costs				
Variable				
Silica flux	ton	10.00	0.80	8.00
Fuel oil	MMBtu	2.00	12.70	25.40
Natural gas	MMBtu	2.00	1.30	2.60
Electricity	kwh	0.03	370.00	11.10
Water: process	Mgal	0.05	1.00	0.05
cooling	Mgal	0.08	2.00	0.16
Refractories	ton	360.00	0.01	3.60
Direct operating and maintenance labor (L)	Man-hour	9.00	6.00	54.00
Supervision (S)	L	15% L	-	8.10
Overhead	(L&S)	65% (L&S)	-	40.36
Maintenance materials	CI	4% CI	-	40.00
Sub-Total				193.37
Fixed				
Fixed charges		26.3% CI		263.00
Total				456.37
Sulfuric acid credit (in Arizona)	ton	10.00	3.33	(33.30)

Source: Arthur D. Little, Inc. estimates.

TABLE H-2

ORDER-OF-MAGNITUDE OPERATING COSTS FOR AN ELECTROLYTIC REFINERY

	Unit	$/Unit	Units/ Ton Cu	$/Ton Cu
A. Capital Investment (CI)			$450/annual ton	
B. Operating Costs				
Variable				
Sulfuric acid	ton	10.00	0.01	0.10
Fuel oil	MMBtu	2.00	2.00	2.00
Electricity	kwh	0.03	250.00	5.25
Water: process	Mgal	0.20	1.00	0.20
Direct labor (L)	Man-hour	9.00	5.50	49.50
Supervision (S)	L	15% L	-	7.42
Overhead	(L&S)	65% (L&S)	-	37.00
Maintenance materials	CI	4% CI	-	18.00
Sub-Total				119.47
Fixed				
Fixed charges		26.3% CI		118.35
Total				237.82

Source: Arthur D. Little, Inc. estimates

APPENDIX I

JAPANESE SMELTING AND REFINING CHARGES

A. INTRODUCTION

Japan is the largest importer of raw materials in the world. The bulk of these imports are consumed internally and the Japanese exports (mainly finished goods) are to a great extent designed to balance the cost of raw material imports which are required for the functioning of the domestic economy[1]. The actual task of raw material imports is carried out by the large trading companies and associated metal processors. Often trading companies and an associated bank can provide financial backing for undertaking new projects. The division between public and private sectors is blurred in Japan. The principal governmental entity involved in mineral trade is Ministry of International Trade and Industry (MITI). All major transactions have to be cleared by MITI and its day-to-day influence on the activities of the Japanese companies is extensive[2]. In addition, MITI approval is required for capital expenditures abroad over a certain amount, allowing it to control all major overseas resource activity. In addition to MITI, government financial entities are also an important influence since Japanese companies carry a high level of debt financing.

The Japanese economy suffered a recession in 1970-71. This slowdown in industrial expansion caused problems with long-term resource contracts. These problems were the delivery of "surplus" (i.e. unwanted) materials, pollution control measures at the smelters, revaluation of the yen, etc. These problems were resolved through contract renegotiation, force majeure on deliveries and governmental assistance. Since 1973, some of the old policies appear to be continuing e.g. government assistance[3,4,5] while others are undergoing gradual modification. In this latter category is the trend towards greater equity participation in overseas mineral projects (e.g. Cuajone in Peru[4] and CDCP in the Philippines[3]) and a gradual change in the form in which the resources are imported (e.g. import of refined copper instead of concentrates).[6] Since the Japanese smelters are of recent vintage and have had extensive pollution control facilities installed since 1970, it is likely that the importation of refined metals will supplement the importation of concentrates but not replace it until the current technology becomes obsolete.

Canada (British Columbia) and the Philippines are the two largest sources of concentrates smelted in Japan. The development of the mining and milling industry in these two countries has followed similar paths. There was usually a long-term contract for supply of concentrates (6-12 years), little equity or managerial participation by the Japanese and standard smelting and refining terms (see Appendix A). Debt financing provided a significant portion of the total capital requirements and Japanese participation in debt financing was substantial. The contracts used LME refined copper quotations as the pricing basis and contained formulae for calculating the sales price of the concentrate after smelting and refining charges (and freight) were deducted.[7] As shown in Appendix A, these formulae are such that the concentrate value varies as the LME price changes. The smelting and refining charges do not change with the LME price but increase with changes in fuel and labor costs. This approach provides the purchaser with security of supply (limited by the force majeure clause) rather than price stability.

B. JAPANESE SMELTING AND REFINING CHARGES

We do not have in our possession a current smelting and refining contract between a Japanese smelter and a long-term supplier. We have seen such contracts in the past (1969-70) when they contained all the features of the typical contract shown in Appendix A. The published literature[7] suggests that there has not been any change in the structure of these contracts. The following can be gleaned about the current level of Japanese smelting and refining charges.

Mitsubishi's charges are estimated at 14¢/lb (early '77) for treating the concentrates from Atlas Consolidated in the Philippines.[8] The charges to British Columbia mines were estimated to be 13-16¢/lb in late 1976 and the Japanese smelters are trying to renegotiate these charges.[9] The British Columbia miners expect these charges to be about 22¢/lb in the future.[10] We have used an estimate of 22¢/lb as the level of 1978 custom smelting and refining charges in Japan. This is essentially an upper bound since there is some confusion in reference [10] about whether or not the 22¢/lb charge includes shipping costs. In calculating "trigger prices" for the switching of concentrates away from Tacoma, we have assumed that this figure <u>excludes</u> the 3¢/lb shipping charge. If we had assumed that the shipping charge was included, the trigger price would have been lower, and would have shown a more severe impact on Tacoma.

C. TACOMA'S COMPETITIVE POSTURE REGARDING LOW IMPURITY CONCENTRATES

The level of Japanese smelting and refining charges has an important bearing on Tacoma's ability to attract low impurity concentrates from British Columbia or other sources. Asarco has not succeeded in obtaining B. C. concentrates either on a long-term contract or on a "spot" basis (a one-time sale of a batch of concentrates).[11] (The B. C. concentrates smelted at Tacoma have always been acquired on a "swap" e.g. for each ton delivered to Tacoma by Newmont, an equivalent amount is delivered by Asarco to Newmont's smelter in Arizona.) In the case of Granduc (operated by Newmont and ownership split equally between Newmont and Asarco) both Newmont and Asarco have shipped the concentrates to Japan. The above-mentioned behavior of the B. C. mines suggests that the Japanese smelting and refining charges have been lower than Tacoma's. This behavior provides indirect confirmation for the levels of Japanese charges discussed in Section B.

REFERENCES

1) M. A. Galway, "Japanese Involvement in British Columbia Copper" Mineral Bulletin MR 145, Dept. of Energy, Mines and Resources, Canada (1975) p. 7

2) M. A. Galway, "Japanese Involvement in British Columbia Copper" Mineral Bulletin MR 145, Dept. of Energy, Mines and Resources, Canada (1975) p. 11

3) Metals Week, December 20, 1976

4) Metals Week, September 6, 1976

5) Metals Week, August 30, 1976

6) M. A. Galway, "Japanese Involvement in British Columbia Copper" Mineral Bulletin, MR 145, Dept. of Energy, Mines and Resources, Canada (1975) p. 14

7) M. A. Galway, "Japanese Involvement in British Columbia Copper" Mineral Bulletin MR 145, Dept. of Energy, Mines and Resources, Canada (1975) p. 30

8) Engineering and Mining Journal, February 1977, p. 118

9) Metals Week, September 6, 1976

10) Metals Week, November 1, 1976

11) Telephone conversation June 22, 1977 with G. Anderson of Asarco

APPENDIX J

TRANSPORTATION COSTS FOR CONCENTRATES

This Appendix provides the basis for the transportation costs used in this report.

The cost of all movements on railroads in the U. S. is based on published tariffs which are rates approved by the Interstate Commerce Commission. These tariffs do not have built-in escalators and any change in tariffs requires a review and hearing procedure somewhat similar to that required of electric utilities. Table J-1 shows the rates used in the report for the movements in 1978 based on the relevant tariffs as published by Southern Pacific and Pacific Southwest Freight Bureau. All concentrates were assumed to contain 28% copper and 0.07% moisture in order to convert the published freight rates to a uniform basis of ¢/lb of contained copper.

The table also shows a second set of transportation costs based on an assumption of a significant rate increase. These numbers are used in the sensitivity analysis.

TABLE J-1

TRANSPORTATION COSTS FOR CONCENTRATES

Movement	Base 1978 Costs	Higher 1978 Costs for Sensitivity Analysis
	(¢/lb of contained copper)	
1. From Battle Mountain, Nevada		
to Tacoma, Washington	2.0*	4.0
to Hayden, Arizona	2.0	5.0
to West Coast	2.0	4.0
2. From S. Arizona Mines		
to Tacoma, Washington	3.9*	6.0
to Hayden, Arizona	1.0	1.5
to West Coast	2.0	4.0
3. Ocean Freight		
from West Coast to Japan	3.0	4.0
from Northern Peru to Tacoma	3.0	4.0
from Philippines to Tacoma	3.0	4.0
4. Lepanto Port to Philippine Smelter	1.0	1.5

* Weighted average for clean concentrates = 3.5

Source: Arthur D. Little, estimates based on published tariffs and professional judgement.

APPENDIX K

THE SMELTING OF SCRAP AND PRECIPITATES AT TACOMA

Table K-1 shows Tacoma's receipts of various sulfur-free copper-bearing materials.

TABLE K-1

RECEIPTS OF SCRAP AND PRECIPITATES AT TACOMA

(short tons)

Year	Low Grade Scrap	No. 2 Scrap	No. 1 Scrap	Precipitates	Total
1971	468	6,120	135	671	7,394
1972	1,185	8,883	0	3,300	13,368
1973	1,085	10,739	0	3,937	15,761
1974	746	11,499	0	5,465	17,710
1975	198	2,366	0	2,839	5,403

About 70% of the scrap is received (more or less uniformly) from the major urban centers on the west coast (i.e., Vancouver, Seattle, Portland, San Francisco and Los Angeles). The remainder of the scrap is from the mid-west and east. The precipitates are mainly from Duval-Battle Mountain, though precipitates from other mines in the Southwest have been received from time-to-time.

The bulk of the scrap smelted at Tacoma is No. 2 copper scrap which is nominally 96% copper (minimum 94%). Secondary copper smelters (producers of unalloyed and alloyed copper) are major users of this scrap. For example, in 1974, about 80% of the No. 2 scrap generated was consumed by these secondary smelters.[1]

Overall, Tacoma's competitors for these materials are as follows:

- precipitates: other primary smelters
- scrap:
  - other primary smelters
  - secondary smelters of unalloyed copper
  - secondary smelters of alloyed copper (brass and bronze)
  - export market

The specific locations of these potential purchasers are listed in Table K-2.

TABLE K-2

POTENTIAL PURCHASERS OF SCRAP AND PRECIPITATES

A. PRIMARY SMELTERS AND REFINERIES[1]

Anaconda, Anaconda, Montana (S)
Asarco, Hayden, Arizona (S)
Asarco, El Paso, Texas (S)
Kennecott, Garfield, Utah (S&R)
Kennecott, McGill, Nevada (S)
Kennecott, Hayden, Arizona (S)
Kennecott, Hurley, New Mexico (S)
Newmont, San Manuel, Arizona (S&R)
Phelps Dodge, Ajo, Arizona (S)
Phelps Dodge, Douglas, Arizona (S)
Phelps Dodge, Morenci, Arizona (S)
Asarco, Amarillo, Texas (R)
Phelps Dodge, El Paso, Texas (R)

B. LARGE SECONDARY SMELTERS[2,3]

Cerro Copper, St. Louis, Missouri
H. Kramer & Co., Chicago, Illinois
H. Kramer & Co., El Segundo, California
N. Chicago Refiners & Smelters, Inc., N. Chicago, Illinois
Benjamin Harris & Co., Chicago Heights, Illinois
Asarco; Federated Metals, San Francisco, California
Morris P. Kirk & Son, Los Angeles, California

C. SMALL SECONDARY SMELTERS OR SCRAP PROCESSORS[2,3,4*]

Oregon

NL Industries, Portland
Western Smelting & Metals, Dalles
Federated Metals, Portland
Kanematsu Gosho (U.S.A.), Inc., Portland

Washington

Federated Metals, Seattle
Materials Reclamation Co., Inc., Seattle
Non-ferrous Metal, Inc., Seattle
R.E. Van Valey, Inc., Seattle

California

Associated Metals Co. of Oakland, Oakland
Chase Metals Service, Inc., Los Angeles
Pacific Trading Corp., Carson
Kawabata American, Inc., Compton

TABLE K-2 (Cont'd)

Matrix Trading Co., Encino
S-G Metals Industries, Inc., Gardena
Federated Metals, Los Angeles and San Francisco
Aaron Ferer & Sons, Los Angeles
International Minerals & Metals Corp., Los Angeles
Kanematsu-Gosho (U.S.A.), Inc., Los Angeles and San Francisco
Martin Metals, Inc., Los Angeles
NL Industries, Los Angeles
Zenith Metals, Inc., Los Angeles
Levin Metals Corp., Redwood City, Sacramento, Richmond, San Jose, Stockton
Keystone Resources, San Francisco
Gerald Metals, Santa Clara
Hugo New & Sons, Terminal Island
Pacific Smelting Co., Torrance

Arizona

Kolor, Inc., Tucson
Metals Western, Inc., Tucson
Alimico Smelters & Refiners, Phoenix
Capital Wire & Cable, Casa Grande
Mesa Metals, Mesa
Empire Metals, Phoenix

Montana

Mike Chovanak, Helena

Utah

Chado Metal Processing, Salt Lake City
Mackay, B.R. & Sons, Inc., Salt Lake City
United Refinery, Inc., Salt Lake City
Mackay Smelting Co., Inc., Salt Lake City
Metal Processing, Salt Lake City
Harsco Corp., Provo
Metallurgical Sciences, Inc., Provo

Notes: *These are listed as secondary smelters by the sources cited. Some of these might be scrap processors or traders.

Sources:
1. American Bureau of Metal Statistics Yearbook
2. Dunn & Bradstreet
3. National Association of Recycling Industries, Inc.
4. Directory of Manufacturers (State)

The Duval-Battle Mountain mine ships only a part of its precipitate production to Tacoma. The remainder is shipped to southern Arizona for treatment. Battle Mountain is at about the same distance from Tacoma as it is from several western smelters. Thus, if Battle Mountain were to switch to another primary smelter, differential transportation costs would not be a factor in this change (i.e., a shift in relative toll charges, with transportation cost remaining constant, could bring about a switch, in this case away from Tacoma).

As shown in Table K-2, there are numerous potential purchasers/processors of the scrap currently smelted by Tacoma. They are widely distributed geographically, and, in many instances appear to be closer to the scrap sources than is Tacoma. Thus, differential transportation costs would not be a major factor in the switching of this scrap away from Tacoma.

For these reasons, our analysis assumes that the demand function facing Tacoma on the part of the suppliers of scrap and precipitates is perfectly elastic. Thus, Tacoma is a price-taker not a price-setter and would run the risk of losing these supplies if it raises its smelting and refining charges.

REFERENCES

1) U. S. Bureau of Mines, Minerals Yearbook, 1974.

APPENDIX L

ALTERNATIVE APPROACH FOR ECONOMIC IMPACT ANALYSIS

This Appendix presents alternative ways of estimating the economic impacts of five specific options considered in this report. These options are:

4.2B (Browder improvements, particulate control, OSHA)

3.1B (Browder improvements, particulate control, roaster gas enrichment, acid plant consolidation)

3.2B (Browder improvements, particulate control, roaster gas enrichment, acid plant consolidation, OSHA)

1.1B (Electric furnace, particulate control, acid plant consolidation)

1.2B (Electric furnace, particulate control, acid plant consolidation, OSHA)

A. GENERAL FRAMEWORK

For each specific option selected for detailed analysis, the step-by-step analytical process described below was followed:

Step 1: Required Revenues

The annualized compliance costs given in the body of the report were used to compute required incremental revenues and required total revenues in each year, as follows:

$$\Delta R_t = \Delta C_t \text{ and}$$

$$R_t = R_o + \Delta R_t$$

where

ΔR_t: required incremental revenues in year t (t = 1978, ..., 1996);

ΔC_t: annualized compliance costs;

R_t: total required revenue in year t;

R_o: total "base" (1978), in the absence of any incremental control at Tacoma.

R_o is derived as follows: base year output of contained metal (100,060 short tons x 2,000 lbs/short ton) times 22.7¢/lb (which yields $45.4 million) plus revenues from byproduct sales ($3.6 million, including arsenic). The total is $49.0 million.

The procedure in Step 1 assumes, as a first approximation, full cost "pass on" for all mines supplying Tacoma (except for suppliers of scrap and precipitates, whose demand function for Tacoma's services is perfectly elastic at cost 23¢/lb). We will come back to this "first approximation" assumption later; for the present, it should be noted that the purpose is to calculate required revenues and required prices, by year, for a financial analysis of the control option.

Step 2: Required Prices

The required total revenues calculated for each year under Step 1 were used to estimate required price levels at Tacoma, by year, assuming a perfectly inelastic demand schedule for all suppliers of sulfur-bearing materials, (including suppliers of both low-impurity and high-impurity concentrates) and assuming a perfectly elastic demand schedule for suppliers of scrap and precipitates (i.e., no cost "pass on" to this latter group of Tacoma's customers).

For any given year, "required prices" are computed as follows:

Let

R_t: required revenues in year t, in dollars;

Q_1: quantity (lbs) produced by Tacoma from sulfur-bearing materials ("base" or 1978 conditions; Q_1 = 156.12 million lbs);

Q_2: quantity (lbs) produced by Tacoma from sulfur-free sources (i.e., scrap and precipitates), where Q_2 = 44.00 million lbs.

P_{1t}: "required" price, to be solved for each year t (i.e., Tacoma's required price for suppliers of sulfur-bearing materials);

P_2: Tacoma's price for suppliers of scrap and precipitates, which is constant at 23¢/lb;

R_o^{bp}: "base" (i.e., 1978) byproduct revenues (including arsenic revenues), estimated at $3.6 million/year.

Then, we have

$$R_t = Q_1 P_{2t} + Q_2 P_2 + R_o^{bp}$$

from which we can solve for P_{2t} as follows:

$$P_{1t} = \frac{R_t - Q_2 P_2 - R_o^{bp}}{Q_1}$$

Step 3: Resulting Cash Flow and Rate of Return

Given the required revenues and the required prices based on them, the resulting pre-tax net cash flows for each year have been computed (by taking into account yearly capital expenditures, out-of-pocket production costs and fixed G&A expenses). The results have then been used to calculate the internal rates of return for each control option.

In view of the lengthy period of cumulative negative cash flow, standard financial criteria would require the equivalent of about a 20% constant-dollar pre-tax rate of return, given the risk and the apparent risk-adjusted cost of capital. Taking into account variation in debt-equity ratio which might apply to financing the various options, as well as a range in effective Federal income tax rate due to the use of accelerated depreciation and the investment tax credit, we would expect the equivalent pre-tax hurdle rate (minimum expected rate) to fall within the range 15-25%.

If the calculated rates of return would fall below the hurdle rate, the option would be considered weak from a financial analysis standpoint. If, however, the results appeared "favorable,"* a next iteration was followed, noted under Step 4.

Step 4: Microeconomic Analysis

Microeconomic analysis of each control option was conducted to verify the financial results, by closely examining the dynamics of the adjustment process caused by upward shifts over time in Tacoma's pertinent cost functions.

The short-run and long-run demand elasticities of all of the participants in Tacoma's activities were again examined, in order to clarify and identify the options enjoyed by and constraints falling upon each of the participants, taking into account the implications of their respective decisions upon each other and on Tacoma. In this way, an attempt was made to trace, over time, the most likely behavior of each participant, particularly to pinpoint, as closely as possible, when each would make a major move, directly affecting Tacoma's economic and financial performance as depicted by the earlier financial analysis of Step 3.

As part of the microeconomic analysis of each control option, we have further considered the possibility of Tacoma adopting a differential pricing approach, basically to prevent the suppliers of "clean" concentrates from switching to other outlets (e.g., Japanese smelters, own smelters, etc.). The basic concept here would be for Tacoma to charge no more than 27.5¢/lb to suppliers of "clean" concentrates, but to charge a higher price to suppliers of "dirty" concentrates.

---

* Such a description is used advisedly; a discussion of the interpretation of these internal rates of return is given below on page L-5.

The differential price to be charged in any given year to suppliers of "dirty" concentrates can be computed as follows:

Let

R_t and R_t^{by} be as defined earlier; and

Q_1: quantity (lbs) produced by Tacoma from "clean" concentrates (Q_1 = 46,550 short tons/year or 93.00 million lbs/year);

Q_2: quantity (lbs) produced by Tacoma from "dirty" concentrates (Q_2 = 31,560 short tons/year of 63.12 million lbs/year);

R_t^{sp}: revenues in year t from suppliers of scrap and precipitates (i.e., 44.00 million lbs x \$0.23/lb = \$10.12 million), which is given for each year (i.e., constant at the base year level);

P_1: Tacoma's price for suppliers of "clean" concentrates (P_1 = 27.5¢/lb);

P_{2t}: Tacoma's price for suppliers of "dirty" concentrates (Note: P_{2t} is the unknown).

Then, we have

$$R_t = Q_1P_1 + Q_2P_{2t} + R_t^{sp} + R_t^{by}$$

from which we can solve for P_{2t} as follows:

$$P_{2t} = \frac{R_t - Q_1P_1 - R_t^{sp} - R_t^{by}}{Q_2}$$

which, in numerical terms, becomes

$$P_{2t} \quad \frac{R_t - \$25.58 \text{ million} - \$10.12 \text{ million} - \$3.6 \text{ million}}{62.12 \text{ million lbs.}}$$

where R_t depends on R_o and ΔC_t (explained above).

Step 5: Reexamination of Financial Analysis and Conclusions

Following microeconomic analysis of each control option, the earlier financial analysis was reexamined to ascertain its validity and implications for investment decision-making, before reaching firm conclusions (as possible) as to the fundamental conditions under which each option would be considered. For example, in those cases in which the microeconomic analysis and other considerations indicated that sensitivity would be appropriate, we looked at different hurdle rates (Option 1.1B) and at both pre-tax and after-tax results (Option 1.2B).

B. DISCUSSION OF OPTION 4.2B (BROWDER IMPROVEMENTS, PARTICULATE CONTROL, OSHA)

Tables L-1 and L-2 present the required incremental and total revenues and therefore required incremental prices and total price levels, as well as calculations leading to pre-tax net cash flow at Tacoma for each year over the impact analysis period. These calculations, yielding 27.5% internal rate of return[1], reflect recovery of the incremental pollution abatement costs and the assumption that Tacoma's present customers will not switch to alternative service outlets or will not be forced into closure (i.e., full cost "pass on").[2]

Although these financial calculations make Option 4.2B appear favorable, a closer microeconomic examination of these results lead to far less favorable conclusions.

An examination of the required price schedule would show that Tacoma's prices (p_t^T) after 1981 would exceed 27.5¢/lb which is the trigger point for Duval to shift to Japan under conditions of domestic smelter capacity constraints and availability of smelter capacity in Japan. A loss of smelter feed of this magnitude (i.e., Duval and other southwestern suppliers of clean concentrates) would leave Tacoma with only impure concentrate supplies amounting to only about one-third of the baseline concentrate input. A smelter's operating costs increase dramatically when capacity utilization is low.

Furthermore, it appears that Tacoma (or any smelter) would have metallurgical problems if it smelted only impure concentrates, such as Lepanto's. Thus, the loss of Duval[3] would have a "domino effect" in shutting Tacoma down.

Tacoma can, in principle, exercise differential pricing for its services, charging Duval and other southwestern mines only 27.5¢/lb and others a higher price. Under these conditions, Tacoma's required price for the impure concentrates would have to be 29¢/lb in 1982, and 38¢/lb in 1989. This means Asarco/Tacoma has to assume that the copper price will exceed 82-91¢/lb, since this is the copper price range Lepanto would require.[4]

---

[1] The "required price" includes a capital recovery charge to yield 15% DCF rate of return on the incremental investment for pollution control. The cash flow in Table L-2 includes revenues from the ongoing Tacoma operation and hence the rate of return is higher.

[2] Except, of course, to suppliers of scrap and precipitates for whom Tacoma's price would not exceed 23¢/lb, since, beyond this price, they would switch away from Tacoma.

[3] Duval is used here as a surrogate for the southwestern concentrates and other suppliers of "clean" concentrates.

[4] This is estimated as follows: smelting and refining charges (29-38¢/lb) plus transportation (3¢/lb) plus total unit costs of concentrate production (i.e., c^{atc}, estimated at 50¢/lb in 1978 dollars); for Duval, c^{atc} is estimated at 52¢/lb (in 1978 dollars).

TABLE L-1

OPTION 4.2B

CALCULATIONS OF REQUIRED REVENUES AND PRICES FOR TACOMA[a]

	Δ Required Revenue[b]	Total[c] Required Revenue	Tacoma's Required Incremental Price[a]	Total Required Price
	$MM		¢/lb	
1978	--	49.00	0	22.7
1979	1.62	50.62	1.04	23.7
1980	4 84	53.84	3.10	25.8
1981	6.46	55.46	4.13	26.8
1982	8.68	57.68	5.56	28.3
1983	10.90	59.90	6.98	29.7
1984	13.12	62.12	8.40	31.1
1985	13.34	62.34	8.54	31.2
1986	13.56	62.56	8.68	31.4
1987	13.78	62.78	8.82	31.5
1988	14.00	63.00	8.96	31.7
1989	14.22	63.22	9.10	31.8
1990	12.82	61.82	8.20	30.9
1991	11.42	60.42	7.31	30.0
1992	10.62	59.62	6.80	29.5
1993	9.82	58.82	6.28	29.0
1994	9.02	58.02	5.77	28.5
1995	8.22	57.22	5.26	28.0
1996	8.22	57.22	5.26	28.0
1997	8.22	57.22	5.26	28.0

Notes: a. Assumes no loss of concentrate feed.
b. Δ required revenue = annualized compliance costs.
c. Total revenue = Δ required revenue + 1978 ("base") revenue.

TABLE L-2

PRE-TAX CASH FLOW FOR OPTION 4.2B ASSUMING REQUIRED REVENUES ARE OBTAINED[a]

	Total Required Revenues (new receipts)	Capital Expenditures	Out of Pocket Production Costs	Fixed G&A Expense	Pretax Net Cash Flow
	$MM 1978				
1978	49.00	-11.18	-41.00	-3.5	-6.68
1979	50.62	-11.18	-41.00	-3.5	-5.06
1980	53.84	- 7.63	-42.60	-3.5	0.11
1981	55.46	- 7.63	-43.20	-3.5	1.03
1982	57.68	- 7.63	-44.40	-3.5	2.15
1983	59.90	- 7.63	-45.60	-3.5	3.17
1984	62.12	- 2.92	-46.80	-3.5	8.90
1985	62.34	- 2.92	-46.80	-3.5	9.12
1986	62.56	- 2.92	-46.80	-3.5	9.34
1987	62.78	- 2.92	-46.80	-3.5	9.56
1988	63.00	- 2.92	-46.80	-3.5	9.78
1989	63.22	- 2.92	-46.80	-3.5	10.00
1990	61.82	- 2.92	-46.80	-3.5	8.60
1991	60.42	- 2.92	-46.80	-3.5	7.20
1992	59.62	- 2.92	-46.80	-3.5	6.40
1993	58.82	- 2.92	-46.80	-3.5	5.60
1994	58.02	- 2.92	-46.80	-3.5	4.80
1995	57.22	- 2.92	-46.80	-3.5	4.00
1996	57.22	- 2.92	-46.80	-3.5	4.00
1997	57.22	- 2.92	-46.80	-3.5	4.00

Internal Rate of Return = 27.5%

Notes: a. Assumes no loss of concentrate feed.

As long as Asarco/Tacoma's copper price expectations are lower Tacoma would not adopt a differential pricing strategy, for fear of losing Lepanto.

Moreover, about 1983-84[1], when the Philippines smelter is expected to be in operation, Lepanto would obtain smelting and refining services at a price equivalent to Tacoma charges of 30¢/lb (i.e., 33¢/lb less 3¢/lb transportation). Along this line of thinking, one more possibility remains: If the expected lower bound for copper prices is greater than 82-91¢/lb, Lepanto could consider expanding mine capacity and ship its concentrates to both smelters. Asarco/Tacoma is not likely to embark upon a differential pricing course under such an expectation.

Based on the above, we conclude that differential pricing is unlikely to work beyond the time a Philippine smelter comes on-stream. Hence, under these conditions, Duval would find it advantageous to switch to Japanese smelters. This would further precipitate a decision by Lepanto to switch to its home smelter at about the same time. As a consequence, Tacoma would be forced into closure.

Faced now with such a prospect, Asarco/Tacoma is not likely to undertake the incremental pollution abatement expenditures required under Option 4.2B.

C. DISCUSSION OF OPTION 3.1B (BROWDER IMPROVEMENTS, PARTICULATE CONTROL, ROASTER GAS ENRICHMENT, ACID PLANT CONSOLIDATION)

Tables L-3 and L-4 present the required incremental and total price levels as well as calculations leading to net pre-tax cash flows at Tacoma for each year over the impact analysis period. These calculations yield a 30% internal rate of return[2] and reflect the recovery of incremental pollution abatement costs and the assumption that Tacoma's present customers will not switch to alternative outlets or will not be forced to close (i.e., full cost pass on).[3]

Table L-3 shows that Tacoma's prices after 1984 exceed 27.5¢/lb, which, is the trigger point for Duval and other southwestern concentrates to shift to Japan. A loss of smelter feed of this magnitude would leave Tacoma with only impure concentrate supplies amounting to only about one-third of the baseline concentrate input.

The loss of clean southwestern concentrates would have a "domino effect" in shutting Tacoma down.

---

[1]The latest information indicates that the smelter might be in operation before 1981.

[2]The significance of this internal rate of return was discussed earlier in Section B.

[3]Except, of course, to suppliers of scrap and precipitates for whom Tacoma's price has to stay at 23¢/lb. Beyond this price, they would switch away from Tacoma.

TABLE L-3

OPTION 3.1B

CALCULATION OF REQUIRED REVENUES AND PRICES FOR TACOMA[a]

Year	Δ[b] Required Revenue[b]	Total[c] Revenue	Tacoma's[a] Required Incremental price	Total required price
	$MM		¢/lb.	
1978	-	49.00	1.28	22.7
1979	.60	49.60	.38	23.1
1980	2.20	51.2	1.41	24.1
1981	2.20	51.2	1.41	24.1
1982	3.68	52.68	2.36	25.1
1983	5.16	54.16	3.30	26.0
1984	12.14	61.14	7.77	30.5
1985	13.62	62.62	8.72	31.4
1986	13.83	62.83	8.86	31.6
1987	14.04	63.04	8.48	31.7
1988	14.25	63.25	9.13	31.8
1989	14.46	63.46	9.25	31.9
1990	14.07	63.07	9.01	31.7
1991	13.68	62.68	8.76	31.5
1992	13.89	62.89	8.90	31.6
1993	12.62	61.62	8.08	30.8
1994	11.35	60.35	7.27	30.0
1995	10.08	59.08	6.45	29.2
1996	8.81	57.81	5.63	28.3
1997	8.81	57.81	5.63	28.3

Notes:
a. Assumes no loss of concentrate feed.
b. Δ required revenue = annualized compliance costs.
c. Total revenue = Δ required revenue + 1978 "base" revenue.

TABLE L-4

PRE-TAX CASH FLOW FOR OPTION 3.1B ASSUMING REQUIRED REVENUES ARE OBTAINED[a]

Year	Total Required Revenues (Net Receipts)	Modified Required Revenues (Net Receipts)	Capital Expenditures	Out of Pocket Production Costs	Fixed G&A Expense	Pre-Tax Net Cash Flow	Modified Pre-Tax Net Cash Flow
	-----------------	-----------------	$MM 1978	-----------------	-----------------	-----------------	-----------------
1978	49.00	49.00	- 5.18	-41.00	- 3.5	- 0.68	- 0.68
1979	49.60	49.00	- 5.18	-41.00	- 3.5	- 0.08	- 0.68
1980	51.20	50.00	- 1.63	-42.00	- 3.5	4.07	2.87
1981	51.20	51.00	-10.36	-42.00	- 3.5	- 4.66	- 4.87
1982	52.68	52.00	-10.36	-42.00	- 3.5	- 3.18	- 3.86
1983	54.16	54.00	-10.36	-42.00	- 3.5	- 1.70	- 1.86
1984	61.14	58.00	-10.36	-47.50	- 3.5	- 0.22	- 3.36
1985	62.62	60.00	- 2.89	-47.50	- 3.5	8.73	6.11
1986	62.83	60.00	- 2.89	-47.50	- 3.5	8.94	6.11
1987	63.04	60.00	- 2.89	-47.50	- 3.5	9.15	6.11
1988	63.25	62.00	- 2.89	-47.50	- 3.5	9.36	8.11
1989	63.46	62.00	- 2.89	-47.50	- 3.5	9.57	8.11
1990	63.07	62.00	- 2.89	-47.50	- 3.5	9.18	8.11
1991	62.68	62.00	- 2.89	-47.50	- 3.5	8.79	8.11
1992	62.89	62.00	- 2.89	-47.50	- 3.5	9.00	8.11
1993	61.62	62.00	- 2.89	-47.50	- 3.5	7.73	8.11
1994	60.35	62.00	- 2.89	-47.50	- 3.5	6.46	8.11
1995	59.08	62.00	- 2.89	-47.50	- 3.5	5.19	8.11
1996	57.81	62.00	- 2.89	-47.50	- 3.5	3.92	8.11
1997	57.81	62.00	- 2.89	-47.50	- 3.5	3.92	8.11
Internal Rate of Return =						>35%	~25%

Notes: a. Assumes no loss of concentrate feed.
b. Modified by inspection; see text.

Table L-4 shows the effect of modifying required revenues and resulting net cash flow. The required revenue was decreased in years 1981-1992 and increased beyond 1992 in order to decrease the internal rate of return from about 35% to 25%. It can be seen, that in spite of this, the price in 1984 would exceed 27.5¢/lb and trigger the same phenomenon discussed above.

Tacoma can, in principle, exercise differential pricing for its services charging Duval and other southwestern mines only 27.5¢/lb and others a higher price. Under these conditions, Tacoma's required price for impure concentrates would be 34.6¢/lb in 1984 and 37.7¢/lb in 1990. This means that Asarco/Tacoma will have to assume that copper price will exceed 88-91¢/lb since it is the price range that Lepanto would require. As long as Asarco/Tacoma's price expectation is below this range, Tacoma would not adopt a differential strategy for fear of losing Lepanto. (Our estimate of Asarco/Tacoma's expectation of a "floor" price for investment purposes would be about 74¢/lb.)

After the Philippines smelter is in operation, Lepanto could consider expanding mine capacity and ship its concentrates to both smelters. Asarco/Tacoma is not likely to embark upon a differential pricing course under such an expectation.

Based on the above, we conclude that differential pricing is unlikely to work beyond about 1984. Hence, under these conditions, Duval would find it advantageous to switch to Japanese smelters. This would further precipitate a decision by Lepanto to switch to its home smelter at about the same time. As a consequence, Tacoma would be forced into closure. Faced now with such a prospect, Asarco/Tacoma is not likely to undertake the incremental pollution abatement expenditures required under Option 3.1B.

D. DISCUSSION OF OPTION 3.2B (BROWDER IMPROVEMENTS, PARTICULATE CONTROL, ROASTER GAS ENRICHMENT, ACID PLANT CONSOLIDATION, OSHA)

Tables L-5 and L-6 present the required incremental revenues and therefore the required incremental and total price levels as well as calculations leading to net pretax cash flows at Tacoma for each year over the impact analysis period. These calculations yield a 22% internal rate of return[1] and reflect the recovery of incremental pollution abatement costs and the assumption that Tacoma's present customers will not switch to alternative outlets or will not be forced to close (i.e., full cost pass on).[2]

Table L-5 shows that Tacoma's prices after 1982 exceed 27.5¢/lb which is the trigger point for Duval and other southwestern concentrates to shift to Japan. A loss of smelter feed of this magnitude would leave Tacoma

[1]The significance of this internal rate of return was discussed in Section B.

[2]Except, of course, to suppliers of scrap and precipitates for whom Tacoma's price has to stay at 23¢/lb. Beyond this price, they would switch away from Tacoma.

TABLE L-5

OPTION 3.2B

CALCULATION OF REQUIRED REVENUES AND PRICES FOR TACOMA[a]

Year	Δ Re-[b] quired Revenue	Total[c] Revenue	Tacoma's[a] Required Incremental Price	Total Required Price
	--------$MM--------		------------¢/lb.--------	
1978	---	49.00	---	22.7
1979	1.62	50.62	1.04	23.7
1980	4.84	53.84	3.10	25.8
1981	6.46	55.46	4.13	26.8
1982	10.16	59.16	6.50	29.2
1983	13.86	62.86	8.87	31.6
1984	17.56	66.56	11.2	33.9
1985	24.54	73.54	15.7	38.4
1986	24.94	73.94	16.0	38.7
1987	25.34	74.34	16.2	38.9
1988	25.74	74.74	16.4	39.1
1989	26.14	75.14	16.7	39.4
1990	24.92	73.92	15.9	38.6
1991	23.70	72.70	15.2	37.9
1992	23.08	72.08	14.7	37.4
1993	20.98	69.98	13.4	36.1
1994	18.88	67.88	12.1	34.8
1995	16.78	65.78	10.7	33.4
1996	15.70	64.70	10.0	32.7
1997	15.70	64.70	10.0	32.7

Notes:
a. Assumes no loss of concentrate feed.
b. Δ required revenue = annualized compliance costs.
c. Total revenue = Δ required revenue + 1978 "base" revenue.

TABLE L-6

PRE-TAX CASH FLOW FOR OPTIONS 3.2B
ASSUMING REQUIRED REVENUES ARE OBTAINED[a]

Year	Total Required Revenues (Net Receipts)	Capital Expenditures	Out of Pocket Reduction Costs	Fixed G&A Expense	Pre-Tax Net Cash Flow
	$MM1978				
1978	49.00	-11.18	-41.00	-3.5	- 6.68
1979	50.62	-11.18	-41.00	-3.5	- 5.06
1980	53.84	- 7.63	-42.60	-3.5	0.11
1981	55.46	-16.36	-43.20	-3.5	- 7.60
1982	59.16	-16.36	-44.40	-3.5	- 5.10
1983	62.86	-16.36	-45.60	-3.5	- 2.60
1984	66.56	-10.36	-46.80	-3.5	5.90
1985	73.54	- 3.97	-52.30	-3.5	13.77
1986	73.94	- 3.97	-52.30	-3.5	14.17
1987	74.34	- 3.97	-52.30	-3.5	14.57
1988	74.74	- 3.97	-52.30	-3.5	14.97
1989	75.14	- 3.97	-52.30	-3.5	15.37
1990	73.92	- 3.97	-52.30	-3.5	14.15
1991	72.70	- 3.97	-52.30	-3.5	12.93
1992	72.08	- 3.97	-52.30	-3.5	12.31
1993	69.98	- 3.97	-52.30	-3.5	10.21
1994	67.88	- 3.97	-52.30	-3.5	8.11
1995	65.78	- 3.97	-52.30	-3.5	6.01
1996	64.70	- 3.97	-52.30	-3.5	4.93
1997	64.70	- 3.97	-52.30	-3.5	4.93
			Internal Rate of Return		22%

Notes: a. Assumes no loss of concentrate.

with only impure concentrate supplies amounting to only about one-third of the baseline concentrate input. The loss of clean southwestern concentrates would have a "domino effect" in shutting Tacoma down.

Tacoma can, in principle, exercise differential pricing for its services charging Duval and other southwestern mines only 27.5¢/lb and others a higher price. Under these conditions, Tacoma's required price for impure concentrates would be 42.3¢/lb in 1984 and 54.8¢/lb in 1990. This means that Asarco/Tacoma will have to assume that copper prices will exceed the 95-108¢/lb since this is the price range that Lepanto would require. As long as Asarco/Tacoma's price expectation is below this range, Tacoma would not adopt a differential pricing strategy, for fear of losing Lepanto.

After the Philippines smelter is in operation, Lepanto could consider expanding mine capacity and ship its concentrates to both smelters. Asarco/Tacoma is not likely to embark upon a differential pricing course under such an expectation.

Based on the above, we conclude that differential pricing is unlikely to work beyond about 1982. Hence, Duval would find it advantageous to switch to Japanese smelters. This would further precipitate a decision by Lepanto to switch to its home smelter at about the same time. As a consequence, Tacoma would be forced into closure. Faced now with such a prospect, Asarco/Tacoma is not likely to undertake the incremental pollution abatement expenditures required under Option 3.2B.

E. DISCUSSION OF OPTION 1.1B (ELECTRIC FURNACE SMELTING, PARTICULATE CONTROL)

Table L-7 presents another approach to calculating required prices assuming again that Tacoma's present customers will not switch to alternative outlets or will not be forced to close (i.e., full cost pass on).[1] This approach differs from that presented earlier in Tables L-1, L-3 and L-5 in the following fashion:

In the previous tables, the required prices were calculated for each year from annualized cost. These prices resulted in a certain level of required revenues and a pre-tax cash flow. The approach here is to assume a pre-tax discounted cash flow rate of return of 20% and solve for a levelized required price over 1984-93. It can be seen that the required revenues in the early years, i.e., 1978-82 are such that prices are below 27¢/lb. The price in 1983 is 28.4¢/lb and the level price from 1984-93 is 31.9¢/lb.

Table L-7 shows that Tacoma's prices after 1983 exceed 27.5¢/lb, which is the trigger point for Duval and other southwestern concentrates to shift to Japan. A loss of smelter feed of this magnitude would leave Tacoma with only impure concentrate supplies amounting to only about one-third

[1] Except, of course, to suppliers of scrap and precipitates for whom Tacoma's price has to stay at 23¢/lb. Beyond this price, they would switch away from Tacoma.

TABLE L-7

PRICE SCENARIO FOR TACOMA UNDER OPTION 1.1B

Year	Solution: Tacoma Price for Smelting & Refining (¢/1b)	Required Cash In	Cash Out		Present Value of Pre-Tax Cash Flow Discounted at @ 20%
		Revenues	Capital Expenditures	O & M	
		$MM 1978			
1978	22.7	49.00	4.4	44.50	C_1
1979	23.0	49.48	4.4	44.50	C_2
1980	23.8	50.76	15.6	45.30	C_3
1981	25.4	53.14	15.6	45.30	C_4
1982	26.9	55.52	15.6	45.30	C_5
1983	28.4	57.90	15.6	45.30	C_6
1984	31.9	$49.00 + 156(\overline{\Delta p})$	3.5	51.10	C_7
1985	31.9		3.5	51.10	C_8
1986	31.9		3.5	51.10	C_9
1987	31.9		3.5	51.10	C_{10}
1988	31.9		3.5	51.10	C_{11}
1989	31,9		3.5	51.10	C_{12}
1990	31.9		3.5	51.10	C_{13}
1991	31.9		3.5	51.10	C_{14}
1992	31.9		3.5	51.10	C_{15}
1993	31.9		3.5	51.10	C_{16}
					$\sum c_j = -20.12 + 219.1\overline{\Delta p}$

Results: Solve for $\overline{\Delta p}$ with P.V. Cash Flows = 0

$$\overline{\Delta p} = \frac{\$20.12}{\$219.1} = 0.092 = 9.2¢/1b$$

$$P'_{S\&R\ Tacoma} = \text{Base} + \overline{\Delta p} = 31.9¢/1b$$

If Duval drops out, $\overline{\Delta p} = 9.2 \times \frac{156\ \text{MMlbs}}{104\ \text{MMlbs}} = 13.8¢/1b$

$$P''_{S\&R\ Tacoma} = 36.5¢/1b$$

of the baseline concentrate input. The loss of clean southwestern concentrates would have a "domino effect" in shutting Tacoma down.

Tacoma can, in principle, exercise differential pricing for its services charging Duval and other southwestern mines only 27.5¢/lb and others a higher price. Under these conditions, Tacoma's required price for impure concentrates would be 36.5¢/lb beyond 1984. This means that Asarco/Tacoma will have to assume that copper prices will exceed 90¢/lb since this is the price range that Lepanto would require. As long as Asarco/Tacoma's price expectation is below this range, Tacoma would not adopt a differential pricing strategy for fear of losing Lepanto.

After the Philippines' smelter is in operation, Lepanto could consider expanding mine capacity and ship its concentrates to both smelters. Asarco/Tacoma is not likely to embark upon a differential pricing course under such an expectation.

Based on the above, we conclude that differential pricing is unlikely to work beyond about 1983. Hence, under these conditions, Duval would find it advantageous to switch Japanese smelters. This would further precipitate a decision by Lepanto to switch to its home smelter at about the same time. As a consequence, Tacoma would be forced into closure. Faced now with such a prospect, Asarco/Tacoma is not likely to undertake the incremental pollution abatement expenditures required under Option 1.1B.

F. DISCUSSION OF OPTION 1.2B (ELECTRIC FURNACE, PARTICULATE CONTROL, OSHA)

Tables L-8 and L-9 present the required incremental revenues and therefore the required incremental and total price levels as well as calculations leading to net pre-tax and equity cash flows at Tacoma for each year over the impact analysis period. These calculations yield a 19% internal rate of return on pre-tax cash flow. Both tables reflect the assumption that Tacoma's present customers will not switch to alternative outlets or will not be forced to close (i.e., full cost pass on).[1]

If Tacoma were able to receive the revenues and cash flows as illustrated, the resulting pre-tax DCF rate of return would be about 19%. If we assume 30% debt financing on the incremental investment, the after-tax, after interest DCF rate of return would be about 10%. However, cumulative pre-tax net cash flow is negative until 1986, and it would take another 10 years before the positive sum equalled the incremental investment.

Table L-10, a pro-forma P&L statement for Tacoma, illustrates Option 1.2B under a conventional accounting framework, e.g., as might be reported to management and/or stockholders. We have calculated profit margin on sales,

[1] Except, of course, to suppliers of scrap and precipitates for whom Tacoma's price has to stay at 23¢/lb. Beyond this price, they would switch away from Tacoma.

TABLE L-8

OPTION 1.2B

CALCULATION OF REQUIRED REVENUES AND PRICES FOR TACOMA[a]

Year	Δ Required Revenue[b]	Total Revenue[c]	Tacoma's Required Incremental Price[a]	Total Price
	------ $MM	------	------ ¢/lb.	------
1978	----	49.00	----	22.7
1979	1.50	50.50	0.96	23.7
1980	4.40	53.40	2.82	25.5
1981	8.40	57.40	5.38	28.1
1982	13.00	62.00	8.3	31.0
1983	17.60	66.60	11.3	34.0
1984	28.00	77.00	18.0	40.7
1985	28.50	77.50	18.3	41.0
1986	29.00	78.00	18.6	41.3
1987	29.50	78.50	18.9	41.6
1988	30.00	79.00	19.2	41.9
1989	30.50	79.50	19.6	42.3
1990	29.50	78.50	18.9	41.6
1991	28.50	77.50	18.3	41.0
1992	25.60	74.60	16.4	39.1
1993	22.70	71.70	14.6	37.3
1994	19.80	68.80	12.7	35.4
1995	17.45	66.45	11.2	33.9
1996	16.90	65.90	10.8	33.5
1997	16.90	65.90	10.8	33.5

Notes: a. Assumes no loss of concentrate feed.
b. Δ required revenue = annualized compliance costs.
b. Total revenue = Δ required revenue + 1978 "base" revenue.

TABLE L-9

CASH-FLOWS FOR OPTION 1.2B ASSUMING REQUIRED REVENUES ARE OBTAINED[a]

Year	Total Revenues (Net Receipts)[b]	Capital Expen-ditures	Out-Of-Pocket Production Costs	Fixed G&A	Pre-Tax Net Cash Flow[c]	Federal Income Taxes[d] (Credit)	After-Tax, After-Interest, Cash For Equity[d]
	$MM 1978						
1978	49.00	-10.43	-41.00	-3.5	- 5.93	- 0.54	- 6.47
1979	50.50	-10.43	-41.00	-3.5	- 4.43	- 0.26	- 4.88
1980	53.40	-21.61	-42.40	-3.5	-14.11	(0.95)e	-13.54
1981	57.40	-21.61	-43.00	-3.5	-10.71	(1.14)e	-10.34
1982	62.00	-21.61	-44.20	-3.5	- 7.31	(1.09)e	- 7.38
1983	66.60	-21.61	-45.40	-3.5	- 3.91	(0.85)e	- 4.61
1984	77.00	- 4.56	-52.40	-3.5	+16.54	- 1.24	13.36
1985	77.50	- 4.56	-52.40	-3.5	17.04	- 2.11	13.00
1986	78.00	- 4.56	-52.40	-3.5	17.5	- 2.78	12.78
1987	78.50	- 4.56	-52.40	-3.5	18.04	- 3.65	12.45
1988	79.00	- 4.56	-52.40	-3.5	18.54	- 4.18	12.42
1989	79.50	- 4.56	-52.40	-3.5	19.04	- 4.99	8.98
1990	78.50	- 4.56	-52.40	-3.5	18.04	- 5.23	7.93
1991	77.50	- 4.56	-52.40	-3.5	17.04	- 5.36	3.64
1992	74.60	- 4.56	-52.40	-3.5	14.14	- 4.64	1.85
1993	71.70	- 4.56	-52.40	-3.5	11.2	- 3.87	0.07
1994	68.80	- 4.56	-52.40	-3.5	8.3	- 2.86	- 1.43
1995	66.45	- 4.56	-52.40	-3.5	6.0	f	f
1996	65.90	- 4.56	-52.40	-3.5	5.4	f	f
1997	65.90	- 4.56	-52.40	-3.5	5.4	f	f

Notes:
a. Assumes no loss of concentrate feed.
b. Δ required revenue = annualized compliance costs.
c. NPV = 0 @ 19.2% internal ROR.
d. Assumes incremental investment is financed with 30% of debt, 70% equity.
e. Assumes credit available in year for use by paren company.
f. Present value of After-Tax Sums nil for these years.

TABLE L-10

ILLUSTRATIVE TACOMA PRO-FORMA PROFIT AND LOSS STATEMENT-OPTION 1.2B
(millions of 1978 dollars)

BASIS: TABLES V-7, V-21, V-22. SEE TEXT.

Year	Required Sales	Cost of Sales	G&A Expense O.H.	G&A Expense Incremental Interest[a]	Depreciation Book	Depreciation Tax	Pre-Tax Profit Book Basis	Pre-Tax Profit % on Sales	Pre-Tax Profit % on Net Plant	Pre-Tax Profit Tax Basis	Federal Income Tax 48% Book Dep.	Federal Income Tax 48% Tax Dep.	Investment Tax Credit (10% on Cap. Exp.)	Current Taxes Payable (Credit)	Book Net After Current Taxes	Book Return on Beginning Capital (Net Income After Taxes Plus Interest)	Book Return on Beginning Capital % Net Plant	Adjusted[d]
1978	49.00	41.00	3.5	-	1.2	1.2[b]	3.3	6.7%	-	3.3	1.58	1.58	1.04	.54	2.76	2.76	-	-
1979	50.50	41.00	3.5	.19	2.15	3.1	3.66	7.2	8.5%	2.71	1.76	1.30	1.04	.26	3.40	3.59	8.3	11.8
1980	53.40	42.40	3.5	.38	3.10	4.6	4.02	7.5	7.8	2.52	1.93	1.21	2.16	(.95)	4.02	4.40	8.5	11.4
1981	57.40	43.00	3.5	.77	5.06	8.0	5.07	8.8	7.3	2.13	2.43	1.02	2.16	(2.09 cf)[c]	5.07	5.84	8.4	10.6
1982	62.00	44.20	3.5	1.16	7.02	10.9	6.12	9.9	7.1	2.24	2.93	1.07	2.16	(3.18 cf)	6.12	7.28	8.4	10.1
1983	66.60	45.40	3.5	1.55	8.98	13.4	7.17	10.8	7.2	2.73	3.44	1.31	2.16	(4.03 cf)	7.17	8.72	8.6	10.1
1984	77.00	52.40	3.5	1.94	10.9	15.6	8.26	10.7	7.3	3.56	3.96	1.70	.46	(2.79 cf)	8.26	10.20	9.0	10.3
1985	77.50	52.40	3.5	1.94	11.3	14.3	8.36	10.8	7.8	5.36	4.01	2.57	.46	(.68 cf)	8.36	10.30	9.6	11.0
1986	78.00	52.40	3.5	1.94	11.7	13.4	8.46	10.8	8.4	6.76	4.06	3.24	.46	2.10	6.36	8.30	8.3	9.8
1987	78.50	52.40	3.5	1.94	12.1	12.3	8.56	10.9	9.5	8.54	4.11	4.10	.46	3.65	4.91	6.85	7.3	8.9
1988	79.00	52.40	3.5	1.94	12.5	11.5	8.66	10.9	10.1	9.66	4.16	4.64	.46	4.18	4.48	6.42	7.5	9.3
1989	79.50	52.40	3.5	1.94	12.9	10.3	8.76	11.0	11.2	11.36	4.20	5.45	.46	4.99	3.77	5.71	7.3	9.2
1990	78.50	52.40	3.5	1.75	12.6	9.0	8.25	10.5	11.8	11.85	3.96	5.69	.46	5.23	3.02	4.77	6.8	8.9
1991	77.50	52.40	3.5	1.56	12.1	7.9	7.94	10.2	12.9	12.14	3.81	5.82	.46	5.36	2.58	4.14	6.7	9.1
1992	74.60	52.40	3.5	1.17	10.5	6.9	7.03	9.4	13.0	10.63	3.37	5.10	.46	4.64	2.39	3.56	6.6	9.4
1993	71.70	52.40	3.5	.78	9.2	6.0	5.82	8.1	12.0	9.02	2.79	4.33	.46	3.87	1.95	2.73	5.7	8.8
1994	68.80	52.40	3.5	.39	7.4	5.6	5.11	7.4	11.9	6.91	2.45	3.32	.46	2.86	2.25	2.64	6.0	9.4
16-year Average								9.7%	9.6%								7.7%	9.9%

Notes and Sources:
a. 30% debt financing of investment in environment controls with 11-year loans at 6% interest.
b. Normalized estimates.
c. Denotes loss carry-forward.
d. Includes, in addition to net income plus incremental interest, $1.5MM/year of inputed interest associated with ongoing Tacoma operations on the present basis.

Arthur D. Little, Inc., estimates.

return on book value, and return on long-term capital employed in the operations. The latter calculations were performed on two bases: (1) with incremental interest on the incremental investment, and (2) with the sum of (1) plus imputed interest. The imputed interest was assumed to be $1.5MM/year in 1978 dollars, and is built into the fixed G&A expense as a corporate overhead item at Tacoma. The $1.5MM figure seems consistent with the ratio of Tacoma net plant to total Asarco net plant, the proportionate Asarco corporate overhead allocation to Tacoma, and total Asarco interest expense excluding new debt associated with Tacoma.

In comparison with Table L-10, we estimate that the Tacoma complex as it presently exists, would produce pre-tax profit of $3.3MM on sales of $49MM and net plant of $32MM in 1978 dollar terms. Thus, its normal pre-tax profit margin would be 7%, return on book value about 10%, and net income plus interest about 10% of net plant. Adding in normal net working capital, which we estimate at 25% of revenues, the corresponding return on total capital employed would be about 8%.

Table L-11, a pro-forma balance sheet, is a companion table to the P&L projections of Table L-10. We have just shown net plant and net working capital accounts, and have not cast the figures into a complete balance sheet showing the structure of both assets and liabilities. As stated above, we have assumed 30% debt financing for the incremental investment of Option 1.2B for this illustration.

As will be discussed below, the conditions under which Tacoma would be able to achieve this essentially full cost recovery pricing are difficult at best: relatively high copper prices on a sustained basis, plus no less expensive alternatives available to customers. Thus, even with high copper prices, customers may have an incentive to build or utilize more captive smelter capacity, since this is likely to cost less than the cost at Tacoma under Option 1.2B.

Table L-9 shows that Tacoma's prices after 1981 exceed 27.5¢/lb, the trigger point for Duval and other southwestern concentrates to shift to Japan. This loss would have a "domino effect" in shutting Tacoma down.

Tacoma can, in principle, exercise differential pricing for its services charging Duval and other southwestern mines only 27.5¢/lb and others a higher price. Under these conditons, Tacoma's required price for impure concentrates would be 50.7¢/lb in 1984 and 62.1¢/lb in 1990. This means that Asarco/Tacoma will have to assume that copper price will exceed 113-115¢/lb since this is the price range that Lepanto would require. As long as Asarco/Tacoma's price expectation is below this range, Tacoma would not adopt a differential pricing strategy, for fear of losing Lepanto. After the Philippines smelter is in operation, Lepanto could consider expanding mine capacity and ship its concentrates to both smelters. Asarco/Tacoma, is not likely to embark upon a differential pricing course under such an expectation.

Based on the above, we conclude that differential pricing is unlikely to work beyond about 1981. Hence, under these conditions, Duval would find

TABLE L-11

ILLUSTRATIVE TACOMA PRO-FORMA BALANCE SHEET OPTION 1.2B

(millions of 1978 dollars)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Net working capital	12.3	12.6	13.3	14.3	15.5	16.7	19.3	19.4	19.5	19.6	19.8	19.9	19.6	19.4	18.7	17.9	17.2
Net plant beginning year		43.0	51.25	69.75	86.29	100.87	113.50	107.2	100.5	93.4	85.9	78.0	69.7	61.7	54.2	48.3	43.7
Add gross investment less depreciation		8.25	18.5	16.54	14.58	12.6	-6.3	-6.7	-7.1	-7.5	-7.9	-8.3	-8.0	-7.5	-5.9	-4.6	-2.8
Net plant year end	43.0	51.25	69.75	86.29	100.87	113.50	107.2	100.5	93.4	85.9	78.0	69.7	61.7	54.2	48.3	43.7	40.9
Total net assets	55.3	63.9	83.1	100.6	116.4	130.2	126.5	119.9	112.9	105.5	97.8	89.6	81.3	73.6	67.0	61.6	58.1

BASIS: Tables V-7, V-21, V-22, and Arthur D. Little, Inc., estimates. See Text.

it advantageous to switch to Japanese smelters. This would further precipitate a decision by Lepanto to switch to its home smelter at about the same time (about 1983-1984). As a consequence, Tacoma would be forced into closure. Faced now with such a prospect, Asarco/Tacoma is not likely to undertake the incremental pollution abatement expenditures required under Option 1.2B.

APPENDIX M

INCREMENTAL SO_2 CONTROL AND OSHA COSTS

A. INCREMENTAL SO_2 CONTROL

The compliance cost estimates used in our impact analysis for incremental SO_2 control are those estimated by PEDCo Environmental Specialists, Incorporated (Cincinnati, Ohio) as presented in the report entitled "Evaluation of Sulfur Dioxide and Arsenic Control Techniques for Asarco-Tacoma Copper Smelter" (September, 1976).

The PEDCo report shows operating costs (in 1978 dollars) on an annualized basis, where the annualized cost estimates contain fixed charges. However, for an analysis of projected future cash flows at Tacoma, it is necessary to know, separately, initial capital expenditures and direct annual operating and maintenance costs (O&M costs).

The following procedure was used to convert PEDCo's "net annualized operating costs" into O&M costs. The example below refers specifically to PEDCo's Table 3-18 (p. 3-55). The same procedure was used in other cases.

1. Add "credit for sulfuric acid" ($8,431,000) to "net annualized operating cost" ($6,586,000) to obtain "total annualized cost" ($15,017,000).

2. Deduct fixed charges at 17.65% of capital investment ($55,909,000 x 0.1765 = 9,868,000) from the "total annualized cost." Also add back $700,000 "annual credit for replacement of existing acid plant" for reasons explained below. This procedure yields, through subtraction of fixed costs from total annualized costs, the annual O&M costs implicit in PEDCO's estimates for use in our economic impact analysis.

The following issues are pertinent to the use of these deduced annual O&M costs for impact analysis.

1. Accounting for facilities shutdown and resultant savings: If the electric furnace option were implemented Asarco would have to shutdown the reverbs. In Table A-8 (page A-21) PEDCo estimated the incremental annual operating costs for this option. This estimate allowed for credits for (or savings of) natural gas that will no longer be used if the reverbs are replaced. However, PEDCo's estimates of natural gas savings ignored the fact that, in the absence of natural gas, Tacoma would no longer realize a waste heat stream credit which amounts to annual cost savings of about $790,000/year. This would have reduced PEDCo's estimate

of savings that would accrue to Tacoma for not using natural gas from the estimated \$3,154,000/year down to about \$2,364,000/year. In spite of this, we are in general agreement with the general procedure used and have not adjusted PEDCo's estimates for this omission (if we had adjusted PEDCo's estimates, the O&M costs would have increased by about \$790,000).

PEDCo on page A-24 performed a parallel calculation to estimate the savings from acid plant consolidation. We agree with the approach used (i.e., the operation of two acid plants, one old and one new, was compared with the operation of a new, larger consolidated acid plant). PEDCo states that "the savings from building one large plant occur only from the reduced labor and maintenance requirements." Both labor and maintenance are variable costs; yet, the \$700,000 saving was apparently derived by PEDCo by using different fixed charge coefficients.

The validity of the \$700,000 saving can be assessed as follows:

If the controls for the two acid plants are installed in the same control room, the incremental labor is essentially zero or at most an extra person on the day shift costing about \$20,000/year. A common control room is used for acid plants Number 5, 6, and 7 at Kennecott's Garfield smelter.

The maintenance requirements for any plant are estimated at 4-5% of total initial capital investment. (PEDCo uses 4%--see page A-14). For older plants, the relevant capital investment is replacement investment, rather than total initial investment. Thus, the savings on maintenance requirements resulting from plant consolidation may be estimated as follows based on PEDCo's Figure A-8.

Since Asarco's existing acid plant is a single absorption (SA) type, the costs for double absorption (DA) plants given in Figure A-8 have to be discounted by 15-20%.

Saving = Maintenance requirements for existing SA plant @ 160 TPD
+ maintenance requirements of new DA plant @ 400 TPD
- maintenance requirement of new consolidated DA plant @ 560 TPD

$$= 0.04\ (0.8 \times 7.7 \times 10^6 + 13.4 \times 10^6 - 16.4 \times 10^6)$$

= \$128,000/year.

Thus, the probable saving is under \$150,000/year. This is small enough to be ignored.

2. Particulate Control Costs: These relate to the incremental particulate control system agreed to by Asarco as a part of the 5-year variance application of December 5, 1975.

The total cost of these improvements is described in Asarco's application as being from \$4.7 million to about \$5.1 million.

We used the lower figure of \$4.7 million and converted it to a 1978 basis using an inflation escalation factor of 6%/year.

The application for the variance does not give details on O&M costs. These were estimated by us to be about \$0.8 million.

PEDCo's report presents estimates of SO_2 control costs in Chapter 3 and particulate control costs (based on Asarco's application for variance) in Chapter 4. The capital investment figure given in Table 4-2, identical to the cost figure given in Asarco's 1975 variance application but designated "1978 basis", is \$5.1 million. This is within 10% of the number we have used.

PEDCo's annualized cost figure of \$1.4 million is equivalent to an O&M cost of \$0.53 million (Table 4-3). While the table is labeled "Asarco proposal" we were unable to find any O&M cost figures in that proposal. We have hence used an estimated \$0.8 million for O&M costs associated with particulate control.

B. OSHA COSTS

The estimates of compliance costs with OSHA regulations used in this report are from a 1976 report prepared by Arthur Young & Company for U. S. Department of Labor, Occupational Safety and Health Administration, entitled "Technological Feasibility Analysis and Inflationary Impact Statement for the Proposed Standard for Inorganic Arsenic (40 FR 3392)." The compliance costs given by Arthur Young & Company for the proposed standard of 0.004 mg As/m^3 were converted to a 1978 dollar basis.

Other estimates exist for meeting the same standard which are significantly higher. At the OSHA hearing on the proposed standard, Mr. Knowlton J. Caplan, a Board-certified Industrial Hygiene Engineer and President of Industrial Health Engineering Associates, Inc., testified[1] that these costs are understated. His reconstruction of compliance costs at Tacoma, using the same methodology as was employed by Arthur Young & Company, resulted in compliance cost estimates 1-1/2 to 3 times greater than those given in the Arthur Young & Company report.

REFERENCES

1) OSHA rulemaking on Inorganic Arsenic Hearings, Washington, D. C., (September 13, 1976), Exhibit 166.