ROYAL COMMISSION ON FARM MACHINERY

FARM TRACTOR PRODUCTION COSTS

Neil B. MacDonald

William F. Barnicke

Francis W. Judge

Karl E. Hansen

Study No 2

CANADA

ROYAL COMMISSION ON FARM MACHINERY

FARM TRACTOR PRODUCTION COSTS:

A STUDY IN ECONOMIES OF SCALE

prepared jointly by

Neil B. MacDonald, William F. Barnicke
Royal Commission on Farm Machinery

and

Francis W. Judge, Karl E. Hansen
Booz, Allen & Hamilton Canada Ltd.

While this study was prepared for the Royal Commission on Farm Machinery and is being published under its auspices, the views expressed therein are those of the authors and not necessarily those of the Commissioner.

Dr. Clarence L. Barber – Commissioner
Neil B. MacDonald – Director of Research

Available by mail from the Queen's Printer, Ottawa,
and at the following Canadian Government bookshops:

HALIFAX
1735 Barrington Street

MONTREAL
Æterna-Vie Building, 1182 St. Catherine Street West

OTTAWA
Daly Building, Corner Mackenzie and Rideau

TORONTO
221 Yonge Street

WINNIPEG
Mall Center Building, 499 Portage Avenue

VANCOUVER
657 Granville Street

or through your bookseller

Price: $3.00 Catalogue No. Z1-1966/4-2

Price subject to change without notice

Queen's Printer for Canada
Ottawa, 1969

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

FOREWORD

The Commission's decision to carry out an in-depth study of tractor production costs for different levels of output was based on a number of considerations. For many years farmers have complained that the prices at which tractors were sold to farmers in Britain were substantially lower than the price for almost identical tractors in Canada. A Special Report on Prices of Tractors and Combines examines these differences.* In order to understand and explain these differences, as well as to document their existence, a detailed knowledge of tractor production costs under North American conditions was required. Some farmers have also pointed out that tractor prices on a per-horsepower basis do not decline appreciably as the size of the tractor increases, even though one would not expect production costs to increase in the same proportion as size. A study of tractor production costs would provide the data needed to examine this relationship. Further, one of the Commission's terms of reference asked it to assess the competitive position of the Canadian industry in the North American and world markets. The almost complete lack of tractor production facilities in Canada has frequently occasioned comment in the past. To appraise the possibility that Canada might produce tractors on a more substantial scale in the future made necessary a careful study of the costs involved. Finally, the Commission required a general knowledge of the way production

---

* *Special Report on Prices of Tractors and Combines in Canada and Other Countries*, Royal Commission on Farm Machinery, Ottawa: Queen's Printer, 1969.

costs vary with size of plant throughout the farm machinery industry if it was to assess accurately the degree of competition in the industry. For reasons explained in more detail below it was felt that a study of tractor production costs could provide much of the basic data needed for this assessment.

The study of economies of scale -- the way in which costs change as major long-term volume changes occur -- is a difficult process in a complex manufacturing operation involving multiple facilities. Do all costs change at the same rate? Almost certainly they do not. Thus generalizations about production scale, while useful for some purposes, cannot hope to shed much light on the way the many different input costs change in the many stages of complex production processes in a particular industry.

In the farm machinery industry, this complexity is compounded by a wide range of products. As a classification in statistical data, "farm machinery" has only one common factor -- the fact that the purchaser of such equipment lives on a farm. Even if one limits the machinery to machinery used in growing and harvesting field crops, the range and complexity of manufacturing processes represented is very great. At the lowest end of the scale of manufacturing technology are the implements, pulled behind the tractor to prepare the soil bed for the crop to be planted. The implement can be a tool bar, to which chisel plows or cultivators can be attached. Such tool bars, and chisel plows and cultivators, largely require manufacturing facilities concerned with the simple operations of cutting, assembly and welding.

At the other end of the scale of technological complexity are farm tractors, with their high horsepower diesel engines, their power-shift transmissions and their multiple use of hydraulics. Between the tractor and the plow, in descending order of manufacturing sophistication, fall such machines as the combine, the forage harvester, the swather, the hay-baler and the seed-planter.

In studying economies of scale in farm machinery manufacturing, it is likely that the greatest evidence of their existence will be found in the production of the most complex machine, the tractor. Its production will require much technological specialization, which is likely to show more economical utilization of plant capacity as volumes increase. The fact that only the largest companies produce tractors supports this viewpoint.

The Commission, therefore, chose production of the farm tractor for analysis. From this study as a base, general insight into the effect of scale on most of the costs of manufacturing other farm machinery can be deduced, at least in broad terms.

Three production-volume levels, selected to represent the range of tractor manufacturing in North America, are used in the study. The study then makes a detailed series of cost analyses related to the major technological processes involved in tractor production at these different volume levels, using currently accepted process engineering and business management techniques.

A tractor is assembled from a series of parts or components, some made by the tractor manufacturer, and others bought ready for assembly. Depending on the economic decisions of the tractor manufacturer -- which are, of course, heavily influenced by the volume at which he plans to produce tractors -- certain parts will shift from the "make" to the "buy" category. Certain other purchased parts, such as tires, will always be bought because the tractor manufacturer does not have the technical facilities needed for tire manufacturing. There will, however, be some economies of scale in these purchases.

The manufacture of tractors, therefore, can be viewed as the purchase of a number of components to be assembled into the final product along with the other components which are made at the particular volume, given the particular economic constraints and opportunities of the manufacturer in question. The components that will be "made" are the result of three major processes, singly or in combination: foundry, metal casting; metal stamping; and metal machining (from castings, forgings, steel bar stock, tubing, and aluminum) including heat treating, gear cutting, etc. The final operation, no matter the source of the components, is always assembly, where the tractor components are put together to make the end product.

Having decided on the terms of reference and the scope of the study, the Commission was faced with a major problem: who could realistically assess the costs of manufacturing a tractor? The industry-wide data that were available were so imprecise as to be useless. Companies could not be expected to reveal their actual manufacturing costs for publication, and, after certain exchanges with company representatives at public hearings on the question of economies of scale, it became apparent that many had never considered anything further than short-run cost changes in their own analyses.

It became obvious that the only source of useful information would be a study that was at once sound in terms of both design and production engineering, while simultaneously going beyond the traditional concept of an engineering study to include a complete financial analysis of the engineering results. Such a study is really a first-stage feasibility study -- what an existing manufacturer will do in-house or with expert advice before deciding on a new product or plant.

With this in mind, the Commission approached 11 management consulting firms to determine their capacity to undertake such a study. Booz, Allen & Hamilton Canada Ltd. provided the prospectus most responsive to the Commission's purposes and was asked to undertake the work.

Many individuals in the Booz, Allen & Hamilton organizations in Canada and the United States contributed to the original part of the study. It was apparent, however, that it could be extended from its original concept of a cost study to one which discussed the changing level of profits and return on the investments required in the various production processes. Accordingly, members of the Commission staff expanded the study, working with Booz, Allen & Hamilton personnel, to provide the added dimension. Booz, Allen & Hamilton personnel consulted the Commission staff in preparation of the cost data; Commission staff consulted them in turn in preparing the profit data.

Behind the names of the Booz, Allen & Hamilton personnel whose names appear as co-authors on the title page of this study, the Commission is aware of the specialty skills of many individuals. The close contact with this group of specialists explains the degree of confidence which the Commission attaches to the study. Analysts with many years of experience in the processing of parts through different manufacturing operations studied those parts that could be manufactured and determined the material, labour, and machinery inputs required for their production. Other specialists analyzed their work in financial terms against the alternative of buying the part. True, the factory was built and operated only on paper -- but with a disciplined approach that makes the study internally coherent and logical, and closely related to the real world.

The study could not have been carried out successfully without the generous co-operation of those tractor manufacturers who provided -- in spite of strikes, customs delays and, probably, some general exasperation over the Commission's persistence -- tractors and technical details for the Booz, Allen & Hamilton engineers to analyze. Specifically these companies were: J.I. Case Company, Cockshutt Farm Equipment of Canada Limited, John Deere Limited, Ford Motor Company of Canada, Limited, International Harvester Company of Canada, Limited, and Massey-Ferguson Industries Limited. The Commission acknowledges its deep appreciation to the officials of these companies for their assistance in this project and hopes that they will find the report useful and rewarding reading.

As noted above, the study should be considered as having the validity of a first-stage feasibility study. It is a detailed examination of a proposed tractor manufacturing plant done by people who are fully capable of going on to the next stage of operation: the planning, actual construction, and shake-down operation of such a plant. They would be expected to reconcile the actual costs in the final, complete plant with this preliminary study, a significant constraint against over-optimistic cost estimation!

The Commission, however, wishes to establish certain caveats in connection with the study. While maintaining close contact with reality, the study cannot pretend to establish the precise tractor manufacturing costs of any particular company, for reasons that do not, however, affect its validity, or its internal logic:

1. Only three sizes of tractors were studied in detail. In the real world, some eight to ten basic models, with optional gasoline, diesel and liquified propane gas engines would be required to satisfy current market needs, and a

variety of transmission options would also be needed. A full, typical range of accessories was provided, however, for the three tractors studied, so that the plants were made complex enough to handle, store, and install such options as tires, different types of hydraulics, etc.

2. A completely new plant was envisaged, taken after its second year of operation to avoid the "learning curve" effect, but still a completely integrated facility, not having to work with a mix of new and old plant machinery as is common in most actual industrial situations, and with buildings of various ages, at geographical locations more or less suitable to the enterprise.

3. No constraints on availability of capital to the company were considered. In fact, such evidence as is available from annual reports and prospectuses of companies in the industry indicate that there is a considerable pressure on the availability of funds for new investment.

4. Initially, as is normal in developing cost estimates for a manufacturing operation, a regular output flow from the facility was envisaged. Variations in these costs (to relate them to the fluctuations which are normally expected) are discussed in a separate section.

The combination of all these factors would, the Commission feels, overstate to some extent, hopefully small, the costs of tractor manufacturing in North America. In the real world, most companies in this industry reduce their costs by adapting and reconstructing facilities which are at least partly depreciated, rather than building a completely new facility from the ground up. The overstatement of these costs in this study is probably somewhat greater than the understatement of costs caused by the simplified tractor mix and the assumption of capital availability. But the matter cannot be resolved within the study with any greater precision than this statement.

The Commission believes, however, that the study is a very sound indicator of the "average" of such costs, especially in its exposure of economies of scale. The ultimate test of its accuracy would be to build such a plant, and there are already many competent groups in the field capable of doing so. Perhaps some Canadian firm will accept the challenge.

C. L. Barber,
Commissioner.

PREFACE

This study presents the results of our analysis of farm tractor manufacturing. It was undertaken to provide the Commission with an evaluation of the economies of scale in tractor manufacturing, expressed in terms of both costs and profits, and with a numerical foundation for other analyses.

The study was undertaken to provide answers to such questions as:

- What should tractors cost to manufacture when the latest "state-of-the-art" production methods are used at various volume levels?
- What are the factors affecting the make or buy decisions in tractor manufacture and what is the impact of these decisions on fixed cost at various volume levels?
- How much does volume affect the cost of purchased parts?
- How much does volume affect the cost of fabricated parts?
- What opportunities are available to reduce tractor manufacturing cost through the use of standard parts and components between models?
- What would be the difference in return on the investment required at different volume levels?

The study was performed much as a preliminary product cost/profit analysis would be conducted for a manufacturer considering the construction of a new plant. The details of our analytical approach are to be found in Chapter II of the study.

As a result of this examination, manufacturing costs and profits for producing standard tractors at each of the three selected volume levels have been projected. These projections represent idealized costs and profits that would result from very well-managed operations conducted in completely modern facilities and with a constant output of a simplified product mix. Operating costs were determined for each of the major manufacturing areas: foundry, stamping, machining (including heat-treating), and assembly. Cost analyses were also performed for such support functions as materials handling, production control, quality control, etc. While all support functions are provided for at each volume level analyzed, the higher volume levels permitted the provision of a larger number of specialized personnel so that each function could be covered in greater depth. To this extent only, the support functions may not be considered to be equally performed at each volume level. Comparison of the projected total unit costs provides an evaluation of the effect of volume changes on manufacturing costs. The detailed examination by process and function identifies the specific areas of cost differential. The costs projected for the various operations were then related to the outside purchase values identified for the items being made in each process, culminating in the tractor itself. The difference can be considered to be the "profit" earned in a particular manufacturing process and the whole tractor manufacturing establishment. These "profits" allow the development of return-on-investment data for each process, again at the level of an analysis related to consideration of the construction of a new plant.

The impact of short-term fluctuations in volume on manufacturing costs was also explored. At each volume level examined, the terms of reference indicated that the specified facilities should provide the capacity to produce at a rate of 20% above the nominal level to give the kind of normal "reserve" capacity expected in a manufacturing establishment. Operating costs were projected at volumes 20% above and below the three designated volume levels. This analysis was performed on a summary estimate basis and does not have the same degree of accuracy as the data produced during the primary investigation.

A summary comparison was made of the three models examined to estimate cost differences caused by unit size and horsepower. This comparison was based on a review of each major cost factor, but did not involve the operation-by-operation analysis performed for the base, or medium-sized, model. That is, cost differences relating to size and horsepower were projected from the gross differences (in size, for example) of certain major parts. If a casting for the larger or smaller tractor was 25% larger or smaller than the casting for the mid-range tractor, it was assumed to cost that much more or less than the basic casting as far as materials were concerned. Labour and facility costs, however, would not vary by such a percentage.

Another area of less precision is the determination of the cost of purchased components. Letters of inquiry produced little usable price data and the study had to rely on the experience of Booz, Allen & Hamilton analysts to estimate the prices to be paid and the effect of volume on those prices. Possible errors in this area could have influenced the total unit costs significantly. These errors, however, would be fairly consistent between volume levels and would not invalidate the evaluation of economies of scale given a constant make-buy mix; rather a more perfect knowledge of purchase costs might have changed the make-buy mix and thereby affected total unit costs. One of the likely results of a more perfect knowledge of purchase costs would have been to increase the effect of scale economies.

The detailed process planning sheets used by Booz, Allen & Hamilton analysts have not been incorporated in the body of the study, but were bound separately and are available in the Commission's archives. Sample process sheets are included in each process chapter, and more than 100 pages of appendices have been added to support the summary tables and exhibits in the text.

It is with pleasure that we record the contributions made by members of the staff of Booz, Allen & Hamilton, to the study:

Mr. Clyde Dorsett	-	Process Engineer (Foundry)
Mr. Charles Garman	-	Facility Planning Analyst
Mr. Robert Barbrow	-	Process Engineer (Machining)
Mr. Lynn Chandler	-	Manufacturing Engineer
Mr. Richard Croy	-	Process Engineer (Stampings)
Mr. Arlie Brown	-	Design Engineer (Machinery)

We should like to recognize particularly the contribution of Mr. Clyde Dorsett, whose untimely death served to remind all who were associated with the study of his own personal contributions to it.

Finally, we should like to record the pleasure we have had in working with one another on this project. We have felt free to look for new approaches to old problems, not only in the knowledge that we would not be misunderstood among ourselves, but also in the certainty that we had the full backing of the Commissioner in our research. Analysts cannot ask for more.

INTRODUCTION

The following analysis of the costs of manufacturing farm tractors was designed to develop consistent, meaningful production cost data as the basis for evaluating economies of manufacturing scale, examining final product prices, comparing profitability at different volumes, and answering related questions.

1. OBJECTIVES OF THE STUDY

Specific objectives were to:

(1) Identify and Evaluate Economies of Scale. As unit volume increases, manufacturing costs tend to decrease. A principal objective of the study was to identify and quantify the factors that cause this decrease.

(2) Determine the Costs of the Manufacturing Processes and Support Functions. The Commission requested that costs be projected for each major manufacturing process at selected volumes (20,000, 60,000, and 90,000 tractor units a year, representative of the current North American industry), using the modern engineering and business management techniques employed by major manufacturers to predict product costs. These costs were to include all expenditures for such elements as material, labour, and facilities. The costs of related support operations, such as materials handling, production control, and accounting, were also to be explored.

(3) Explore the Effect of Short-Term Fluctuation in Volume. Short-term variations in output are typical in tractor manufacture. The effect of these fluctuations on such cost

elements as overtime premiums, supplemental unemployment benefits, and fixed cost allocations was to be projected for levels 20% above and below each planned volume level.

(4) Examine Cost Differences between Tractor Model Sizes. Certain manufacturing costs vary widely for different model sizes while others vary slightly or not at all. The variation in each major cost element (labour, materials, etc.) was to be projected for the three models examined.

(5) Identify Potential Cost Reductions that Could Be Achieved through Design Improvement. An engineering study was made to identify design changes that would simplify tractor manufacture and reduce its costs. This study was based on mathematical simulations of operating conditions and component performance.

A general objective was to produce a comprehensive report that could be read with understanding by persons not versed in manufacturing technology, and also provide sufficient data to enable the technically competent reader to follow the details of the analysis and understand the results.

2. SCOPE OF THE STUDY

The study was limited to the manufacturing operations and support functions required to produce the standard wheeled farm tractor. The industrial tractor, derived from the farm tractor and currently accounting for close to 20% of the tractor market in North America, was not separately considered. Costs related to design and development, distribution and sales, and corporate administration were not explored. In other words, the costs developed are those of operating a manufacturing plant rather than of a total corporate endeavour. The costs developed are based on 1967-68 cost data and proven technology operational in this period.

Figure 1, following this page, prepared from data supplied by the Commission, illustrates the proportion of the suggested retail price* normally represented by basic manufacturing costs. It shows suggested retail and wholesale price levels for the four largest Canadian farm machinery firms, each producing a different mix of farm machinery in Canada. World manufacturing costs relative to world selling prices are shown for five major farm machinery companies. The manufacturer's price to the dealer is made up of these manufacturing costs plus the cost of product development, sales, service, other corporate functions, and the manufacturer's profit. The dealer, in turn, adds his distribution costs and profit to the final sales price. As shown in Figure 1, manufacturing costs appear to constitute a major portion of the manufacturer's suggested retail price (53-60%) but are by no means the only significant factor.

The costs examined in the study were those related to the production of complete tractors only. The costs of producing replacement parts were not considered. Costs in this area vary widely, as a result of such factors as the number of models in the field and management's policy on providing service to older models.

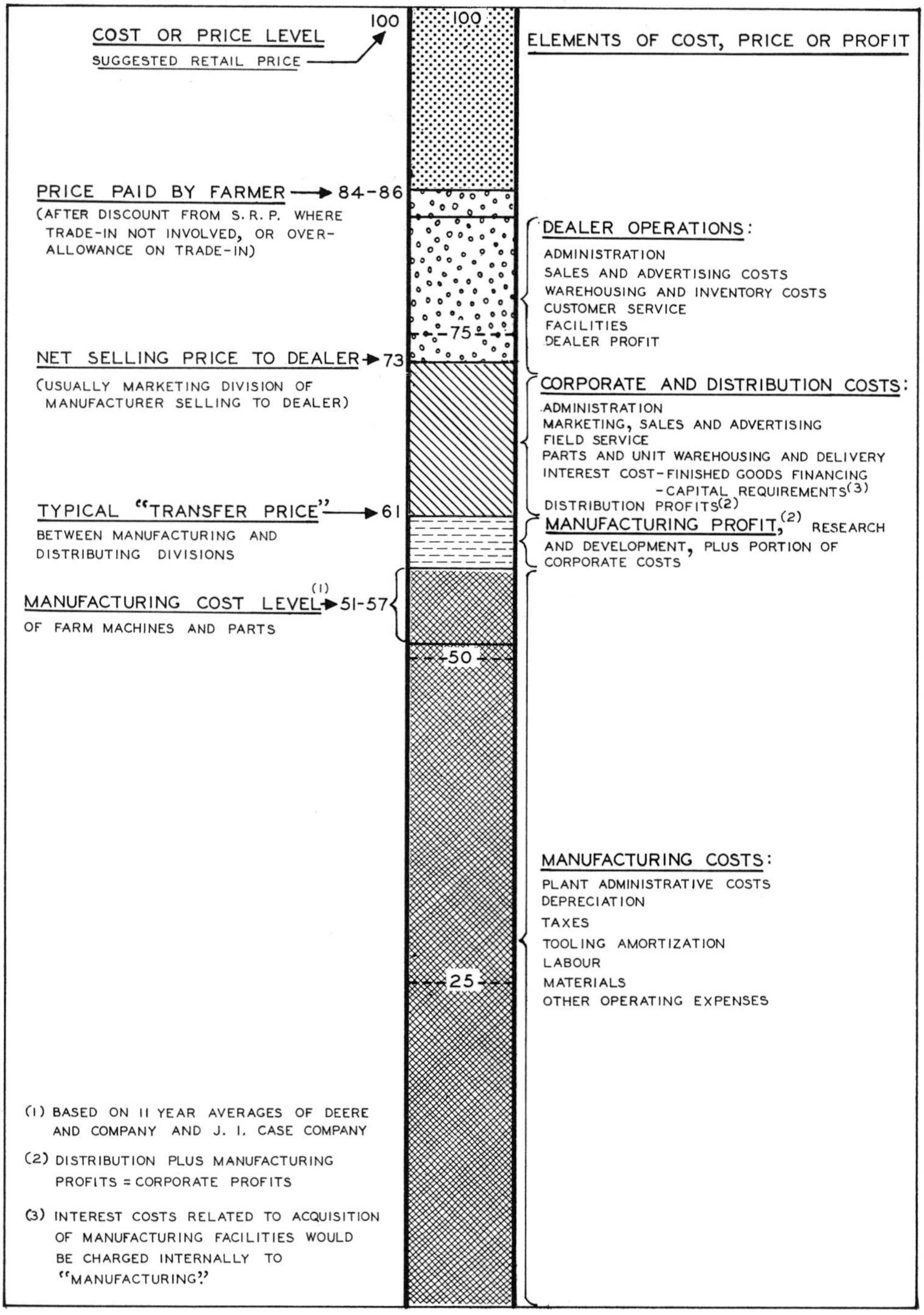
Facility costs, such as depreciation, insurance, taxes, and capital charges, were based on detailed projections of the building space and equipment required. Facilities projections provided for capacity 20% in excess of the designated annual volumes. This capacity was provided to accommodate the seasonal

---

* Throughout the studies published by the Commission, the words "suggested retail price" are intended to cover the retail list price shown in the manufacturers' price lists under a wide variety of titles. "List price" is sometimes used, but is not considered appropriate by the Commission to cover this precise definition because there is also a "wholesale" or dealer's list price, and possible confusion between the two could result.

FIGURE 1

PRICE AND COST LEVELS FOR NEW MACHINES
IN THE NORTH AMERICAN FARM MACHINERY INDUSTRY



fluctuations encountered in the farm machinery industry and represents an excess cost over the minimum cost possible at each of the planned levels.

The study required the application of several technical disciplines: manufacturing and tooling engineering to plan the production operations; industrial engineering to establish labour and material requirements; and mechanical and design engineering to identify potential design improvements. These disciplines were supplemented by expertise in such areas as cost accounting, data processing, and managerial organization.

It is important to reiterate that this study was limited to the determination of manufacturing costs only; the other costs affecting the retail price of a tractor were not examined. These other costs, such as research and selling expenses, are subject to economies of scale and also to large differences caused by variations in corporate policies.

II

THE ANALYTICAL APPROACH

The basic approach used to evaluate economies of scale in tractor production required projecting the cost of manufacturing a particular product mix at each of several selected output volumes. In developing these manufacturing cost projections, all elements of manufacturing costs were examined.

Six major North American farm tractor manufacturing companies lent tractors to the Commission to support this study. These tractors were in the three classes described in Table 3, and were selected so as to be closest to the horsepowers noted. The individual makes and models of tractors studied are described in Table 1.

TABLE 1

TRACTORS LENT BY FARM MACHINERY MANUFACTURING COMPANIES

	Small		Medium		Large	
Company	Model	HP	Model	HP	Model	HP
J.I. Case	541G	40	831D	65	1031D	102
Cockshutt (Oliver)	1250G	38	1750D	80	1950D	106
John Deere	2020G	54	4020D	95	5020D	133
Ford Motor	3000G	38	5000D	55	Not available at time of analysis	
International Harvester	F-544G	52	F-756D	77	I-1256D	113
Massey-Ferguson	135G	35	I-175D	64	1100D	94

G - Gas
D - Diesel
HP - PTO Horsepower

Selected tractors, chosen as representative of the horsepower categories, were dismantled, in whole or part, to determine the parts specifications, materials, and finish required for each size of tractor to be considered for production. Manufacturers' parts specifications and manuals, as well as plant visits, were used to supplement the dismantling operation. Detailed cost estimates for the manufacture or outside purchase of these parts were then developed.

Manufacturing costs normally are categorized as either variable or fixed. Variable costs include those incurred for labour, material, and supplies and certain other costs which are, in some way, related to volume. Fixed costs include such items as depreciation, taxes, tooling amortization, and interest, which are more or less permanently incurred at the time of initial investment and continue even when production is temporarily curtailed. In practice, manufacturing costs are historical tabulations of the expenses incurred to produce the end product plus the cost of owning and operating the productive facilities. Facility costs include both actual disbursements, such as taxes and insurance premiums, and prorated allowances, such as depreciation.

When analyzing the dynamics of a manufacturing operation, it is necessary to study all cost elements and the way they are affected by volume changes. In lieu of having historical data from operating concerns, it was necessary to synthesize these costs. In effect, hypothetical manufacturing plants were created for each of the volume levels examined. The costs of operating these plants were then estimated. The analytical steps involved are described in the paragraphs that follow.

1. COST DETERMINANTS NOT DIRECTLY RELATED TO SCALE WERE HELD CONSTANT

Manufacturing managers make use of the technique of break-even analysis to predict profits at various volumes. Income from sales is plotted against fixed and variable costs to determine the volume at which costs equal income (the break-even point) and the amount of profit, or loss, at other volumes. Items that change the location of the break-even point are the following:

- Volume of output.
- Selling prices.
- Product mix.
- Managerial competency as reflected by performance of labour and utilization of materials and machinery.
- Change in manufacturing technology or facility costs.
- Externally determined cost factors, such as wage rates and material prices.

Selling prices were not included in the scope of this study and, therefore, are not an issue. A valid evaluation of the effect of scale (volume of output) required that all other factors be held constant except as they are affected by volume only. Thus, by holding the extraneous factors set out below constant, the cost effects related to scale changes were isolated.

To satisfy this requirement, the following study parameters were established.

(1) Representative Tractor Models Were Selected for Cost Analysis. From the several models furnished by the manufacturers, three were selected as representative of the assumed mix. Table 2 below presents the configuration data for these three models.

TABLE 2

CONFIGURATION OF TRACTOR MODELS SELECTED

Approximate Horsepower	Fuel	Transmission	PTO	Steering	Rear Tire Size	Option 1 or 2 *
40	Gasoline	Manual	2-speed	Manual	12.4 - 28	1
90	Diesel	Manual	2-speed	Power	18.4 - 34	2
130	Diesel	Manual	2-speed	Power	24.5 - 32	2

* 1 – Remote cylinder control, side frames, one remote cylinder, three-point hitch, air pre-cleaner and pre-screener, coolant heater, electric horn.

2 – As above, without side frames, but with exhaust muffler cover.

The costs of producing the selected models were estimated. The cost of offering additional models and options are reflected only in that assembly and warehouse floor space was provided to permit stocking and installing the usual range of optional auxiliary equipment. Inclusion of a typical variety of basic configurations such as engine and transmission options would increase the man-hours and machine time devoted to setup changes and also increase inventory requirements.

(2) *Product Mix Remained Unchanged.* The manufacturing of the same tractor models and the same proportion of each model were assumed at each output level. The assumed product mix (Table 3) was the combination of low, middle, and high horsepower models currently prevailing in the North American market.

TABLE 3

TRACTOR PRODUCT MIX

Approximate Horsepower	Representing Group	Horsepower Range Covered	Percentage of Plant Volume
40	Low horsepower	Less than 50	30
90	Medium horsepower	51 - 99	60
130	High horsepower	100 and over	10

The percentage volume shown for the high horsepower tractor is somewhat larger than the current percentage of the market represented by this size range. It represents, however, the current direction of the market and is therefore appropriate for product planning purposes.

(3) Managerial Decisions Were Made within a Consistent Frame of Reference. All related decisions were made by the same analysts and within similar policy and numerical constraints. A consistent effort was made to develop the optimum manufacturing situation for each output level. While all support functions are provided for at each volume level analyzed, it was possible to provide a larger number of specialized personnel as volume levels increased. In turn, these larger numbers permitted each function to be covered in greater depth. To this extent only, the support functions may not be considered to be equally performed at each volume level.

(4) Consistent Operating Practices Were Assumed. A uniform two-shift operating schedule was used as a basis for facility and staffing decisions. Labour performance and operating efficiency levels were fixed.

(5) A Consistent Degree of Technological Advancement and Facility Modernization Was Specified. All facilities were designed to incorporate the most modern, proven technology. All machinery and equipment was assumed to be fully operational, but in "like new" condition. Depreciation and other facility costs were calculated on a consistent basis, as provided by the Commission for this study, to represent current practices in the industry.

(6) External Cost Factors Were Applied Uniformly. Such factors as wage rates, building costs, and raw material prices were assumed the same at each output level with one exception: the prices of purchased items were adjusted to reflect anticipated changes caused by varying purchase volumes. This purchase price variation is discussed in Chapter III.

2. ANTICIPATED MANUFACTURING COSTS WERE DEVELOPED AT THE SELECTED OUTPUT LEVELS

Manufacturing cost studies were conducted at each of three volume levels selected by the Commission. The anticipated costs were developed as follows:

(1) Tractor Components Were Reviewed as to the Relative Economies of Manufacture or Purchase. A "make-or-buy" decision was made for each component at total plant annual production levels of 20,000, 60,000, and 90,000 units per year. The items to be purchased were then reviewed to determine their costs at the various purchase volumes.

(2) Key Fabricated Components Were Selected for In-Depth Analysis. A small number of the items to be fabricated represent the bulk of manufacturing cost. This fact is generally true of complex manufactured products and permits the identification of a major portion of the total manufacturing cost by analysis of a relatively small number of components. Table 4 lists, by type,

TABLE 4

SIGNIFICANCE BY NUMBER AND VALUE OF FABRICATED COMPONENTS

OF MEDIUM-HP TRACTOR

SELECTED FOR DETAILED ANALYSIS AT 60,000-UNIT VOLUME LEVEL

	Percentage of Tractor Component Cost Represented by Category	Total Number of Fabricated Components Considered	Number of Components Selected for Analysis	Percentage of Total Number Analyzed	Percentage of Total Estimated Procurement Cost Analyzed
Castings, not machined	4.1	25	25	100	100
Stampings	11.8	161	23	14	69
Machined parts					
-- from castings	27.6	99	33	33	77
-- from forgings	7.5	16	7	44	71
-- other	8.0	130	5	4	13
Total	59.0	431	93	22	69

the number of components selected at the 60,000-unit volume level for detailed study. It also indicates the percentage of the outside purchase costs of all components represented by the components selected for analysis, if valued at the price which would be paid for outside purchase at the 60,000-unit volume. Appendix 1 presents a complete list of parts selected for this detailed analysis. The bias towards the analysis of high-cost parts is recognized, but these are the parts which a tractor manufacturer himself would review in detail.

(3) The Manufacture of these Key Components Was Planned in Detail. Manufacturing engineers developed complete procedures for fabricating the selected parts. The operations to be performed, the machinery and equipment required, and the labour and material inputs needed were specified through the use of detailed process sheets similar to those in Figures 4 and 5 (in Chapter IV). This analysis was initially performed at the 60,000-unit level and adjusted for the changes necessary to accommodate most economically the same result at the other selected volume levels.

This examination required the development of procedures for production scheduling. The basic concept employed was that of weekly scheduling. That is, the setup for a particular component would be made weekly and the number of units of each component required during one week produced as a single batch.

The selection of a weekly cycle was based largely on the economics of operating the foundry molding lines, machining lines for major components, and assembly lines. Scheduling batches in terms of weekly requirements facilitates the scheduling of major change-overs and establishes a simple and practical concept of production control.

In actual practice, the costs of mechanical setups would be balanced against those of carrying components in inventory to establish the optimum batch size for each item. Rough calculations indicated that cost penalties resulting from this simplified treatment were not significant to this study.

Time estimates for each operation analyzed were determined using accepted systems of work measurement, such as the methods time measurement (MTM) system. In addition, standard data available in each industry for processing operations were applied. These data have wide acceptance in industry and are usually used to determine "measured day work standards of production". The basis of wage payment was considered to be the measured day work system. This analysis provided the basic data for determining both direct costs and facility requirements for the processes involved in component fabrication.

(4) Component Fabrication Costs Were Developed. Labour, materials, and facilities requirements for fabrication of analyzed components were extrapolated to include those components not analyzed in detail. These extrapolations were made on a proportional basis, according to the number of components, size of components, value of components, or other bases appropriate to the process being examined, based on the analysts' experience as to which method of extrapolation was most appropriate. The particular basis considered appropriate to each process area is specified in the relevant chapter.

Labour and material requirements were assigned dollar values and facility overhead costs were developed. All these factors were combined into total fabrication costs for founding, stamping, and machining. Chapters IV, V, and VI present the details of these analyses.

A forge shop was not examined in detail because it could not be economically justified even at the highest volume production considered. There are also technological trends away from forging to casting under more carefully controlled conditions and using special metallurgical formulas.

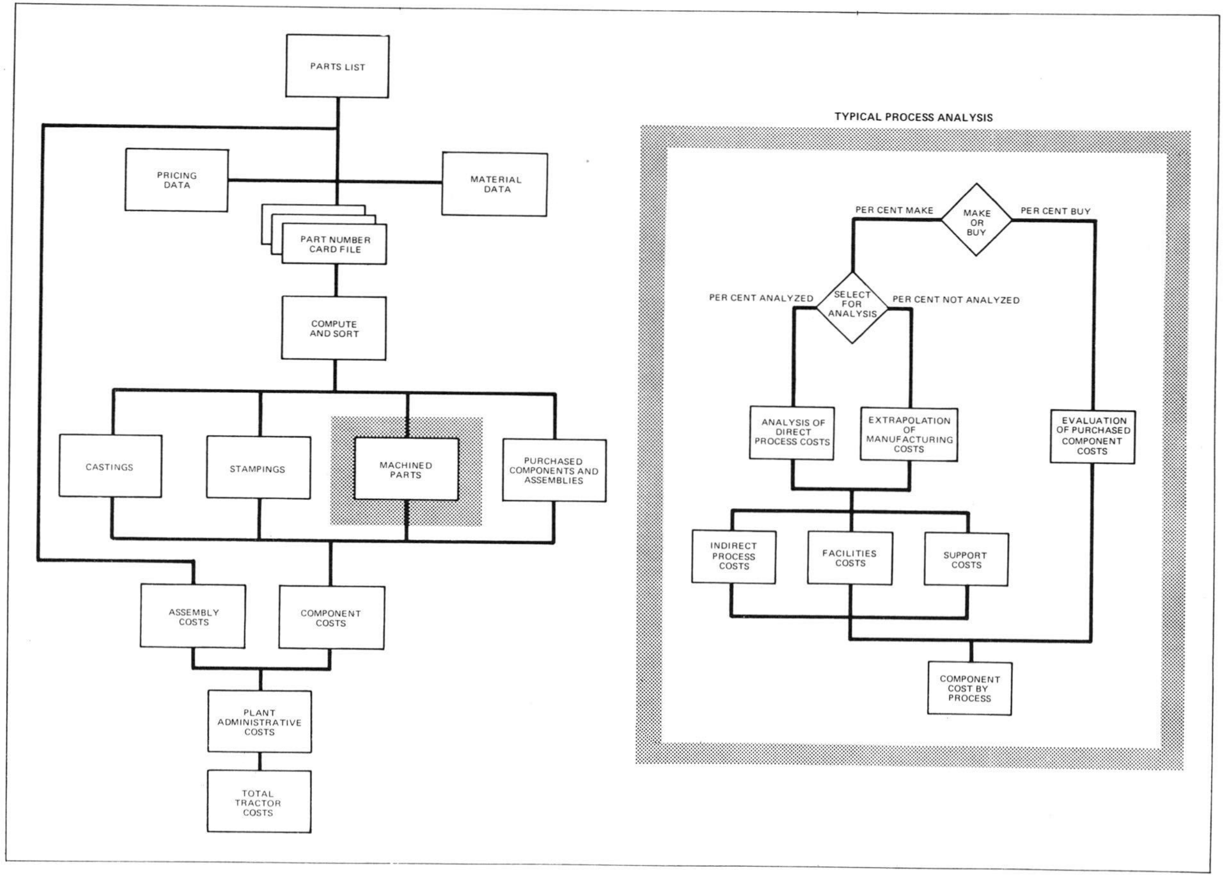
(5) Assembly Costs Were Examined. Production of the major subassemblies and assembly of the tractor itself were examined in the same manner as the fabrication operations. All cost elements were evaluated to develop the total assembly cost for each volume level. Provision was made for purchasing, storing, and installing the range of purchased options associated with tractor manufacturing. Chapter VII reviews this examination.

(6) Administrative and Support Costs Were Projected. The administrative and support staff, materials handling and storage facilities, and other manufacturing overhead cost factors were determined in appropriate sizes for each production volume. Thus, while all required administrative and support functions were covered at all production levels, the administrative and support functions could be carried on with greater specialization at higher volumes. The increase in the absolute number of specialist personnel is one of the sources of the economies of scale related to higher volumes. Except for the purchasing cost changes (noted earlier) it is the only area where a functional change occurs, where an extraneous factor is necessarily affected by volume. Payroll and facility costs were calculated to determine total costs of the support functions. These are found in Chapter VIII.

(7) Total Unit Cost and "Profit" Data Were Developed. All of the cost elements examined earlier were combined to develop the total manufacturing cost per unit. From the total manufacturing costs, manufacturing "profits" for each process (foundry,

FIGURE 2

LOGIC DIAGRAM FOR TRACTOR COST ANALYSIS



stamping, machining, and assembly) were developed. The costs were reviewed to determine the effect of temporary fluctuations from the planned volumes and of shifts in product mix. These summary analyses appear in Chapter IX.

3. <u>OPPORTUNITIES FOR REDUCING MANUFACTURING COSTS THROUGH TRACTOR DESIGN CHANGES WERE IDENTIFIED</u>

A special study was made to identify opportunities for reducing manufacturing costs through design changes that would simplify component fabrication without sacrificing functional performance.

* * *

The study approach described above is diagrammed in Figure 2. This diagram provides an overview of the logic flow and analytical technique described in the chapters that follow.

III

EXAMINATION OF FACTORS THAT AFFECT THE MAKE-OR-BUY MIX OF TRACTOR COMPONENTS

The management of a manufacturing concern has as a principal objective the achievement of maximum return on investment. Other objectives are corporate survival, industry leadership, and consumer satisfaction. Meeting these objectives requires that the management select the "right" investment alternatives. Regardless of whether investment capital is borrowed, derived from stock offerings, or generated by operating profits, its utilization is a crucial test of managerial competency.

One critical element of investment analysis is the continuing search for the combination of fabricated and purchased components that will provide the highest return. Components that cost less to make than to buy must be identified and their potential profit contribution evaluated. This evaluation requires comparing the return on capital to be invested in manufacturing facilities to the return from a large number of relevant alternative investments.

Since purchased components represent a major part of total manufacturing costs (55% at the 20,000-unit volume and 45% at 90,000-unit volume) and since the make-buy mix varies with volume, the objectives of the study required that a make-or-buy examination be made at each selected output level. Further, it was necessary to evaluate the effect of scale on the price of the items to be purchased.

1. THE BASIC OBJECTIVES OF MAKE-OR-BUY ANALYSIS WERE ESTABLISHED

As previously stated, management has a tremendous number of alternative possible uses for corporate funds. Before capital is committed to facilities to produce a particular component, a thorough review of the economics of both fabrication and purchase is required. Economic studies of this nature are called "make-or-buy" analyses. The effect of managerial make-or-buy decisions can be substantial in areas such as the utilization of existing facilities, plant capacity requirements, replacement of obsolete plant facilities and equipment, retention of the labour force during slack periods, and the use of overtime to meet seasonal demands.

(1) Make-or-Buy Analyses Are Based Primarily on Economic Factors. Cost is usually the major criterion in a make-or-buy decision. Will it cost less to buy the part than to make it? To answer this question, fabrication costs must be stated realistically, so that when they are compared with purchase costs the real effect on total manufacturing costs can be determined.

The fabrication cost used for analysis must reflect the cost of the capital required and differentiate between new investment and the utilization of capacity already in existence. It must also reflect true labour costs. For example, given the basic decision to have a foundry, because its full costs can be justified to produce a range of castings, any further available capacity in the foundry should be utilized, even though only a small margin beyond incremental costs can be recovered. A particular component may be produced with underutilized labour during a slack period and purchased during a period of overtime operation, although this can present major planning, scheduling and quality problems to management. With obsolescent plant facilities and equipment, the decision may be to carry on temporarily, even though replacement at current costs cannot be justified for either the same or new, improved equipment. Alternatively, it may be cheaper to buy the component than replace the equipment, particularly if a technological change is anticipated.

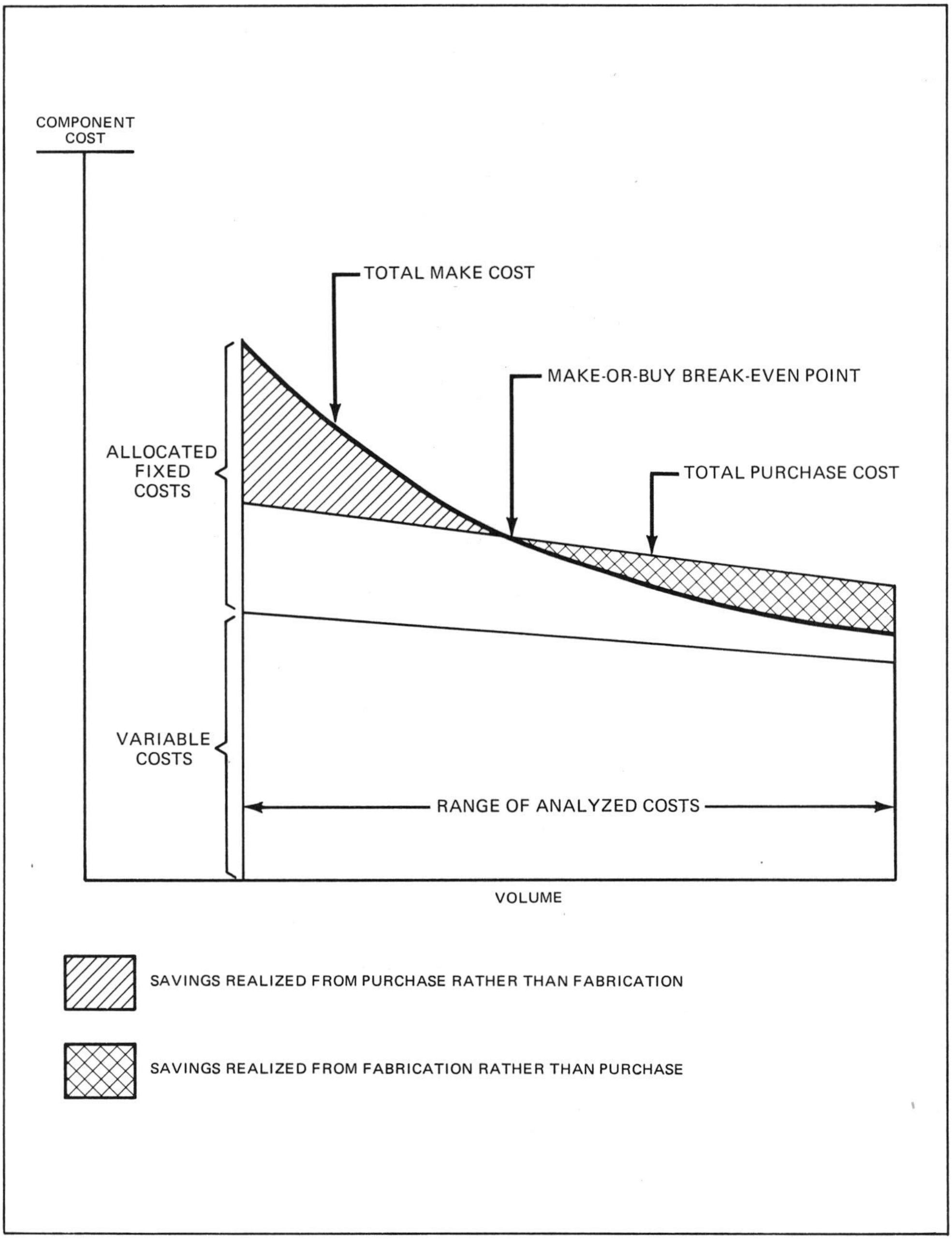
When analysis indicates that the costs of purchase and fabrication are approximately equal, the usual course is to refrain from a major investment in specialized facilities, unless a volume increase is expected. Since fixed volumes were provided by the Commission for this study, this conservative policy was followed during the make-or-buy examination made by the analysts.

When considering the purchase of additional productive equipment, the analysts used as a requirement for its justification a pre-tax rate of return of 20%. This figure is more commonly used to evaluate individual investment alternatives than is the minimum cost of capital (7.5%). The basis is that marginal investments should produce a return after taxes that is substantially above the market cost of the funds involved. The additional amount may be considered to cover the risks and uncertainties in the decision and to perform a rationing function for capital projects.

(2) Volume Directly Affects the Economics of Make-or-Buy Analysis. Assuming a uniform level of technological advancement and managerial competency at the vendor's plant and in the tractor company, the variable costs of production should be the same for in-house and purchased fabrication at the same production volume level. However, a vendor may have several customers for a particular component and be able to take advantage of economies of scale that are not available to a single assembler. These economies normally are achieved in the area of fixed costs that can be spread over the larger number of units. The hypothetical

FIGURE 3

HYPOTHETICAL MAKE-OR-BUY COST CURVE



make-or-buy cost curve, shown in Figure 3, illustrates the effect of volume on fixed and total unit cost.

Figure 3 compares the cost of in-house manufacture with the cost of purchasing from a vendor. At low volume, the vendor can offer a lower net cost, even though the cost of purchasing from him must include provision for his profit and the payment of freight charges. As volume increases and fixed costs become a smaller portion of total unit cost, in-house manufacture becomes more advantageous, in that fabrication costs decrease more rapidly than vendor selling prices.

The factors that result in lower fabrication costs per unit as a result of increases in volume are examined in the chapters that follow. These same factors exist in both in-house fabrication and the vendor's plant. The sharper decline in fabrication costs as opposed to purchased price results from the assumption that the vendor has already reached a flatter portion of the cost reduction curve and the fact that the individual tractor manufacturer would generally have little power to recover volume profits from large, specialist component vendors.

(3) Make-or-Buy Decisions Can Be Affected by Factors other than Manufacturing Costs vs. Purchase Price. It is necessary to emphasize the difference between a make-or-buy analysis which examines costs and prices and the make-or-buy decision itself. The final decision can be affected by a number of factors other than the cost-price relationship. Some of the factors that favour in-house fabrication are: quality, reliability, flexibility, and availability of supply; use of research and development facilities; and control of patents. Factors that favour purchasing a part are: ensuring alternative sources of supply and vendor good will and reciprocity (the reciprocal purchase of each other's products or services by two firms).

A decision to "buy" involves no fixed costs to the tractor manufacturer, but continuing variable costs at a high level; a decision to "make" involves high fixed costs plus variable costs which become lower with larger volumes. The choice between the two -- "make" or "buy" -- often involves an element of "intuition", "feel", or "market sense" which is difficult to quantify.

(4) Make-or-Buy Policies often Follow Industry Patterns. Within the framework of the economic and noneconomic factors, patterns develop establishing make-or-buy policies on a considerable number of parts without the use of detailed economic analysis. These policies commonly dictate purchases of standard items, such as nuts, bolts, and washers, and items that are out of the main line of effort of the manufacturing organization concerned. In tractor manufacture, this category of parts to be automatically purchased would include tires, batteries, radiators, electrical parts, and certain other items that require the provision of special expertise or facilities.

(5) Return on Investment Rate Used Affects Make-or-Buy Decisions. The decision to make or buy a part was based on several factors relevant to the rate of return on investment. The assumed cost of capital to develop cost estimates was 7.5%. It is therefore included as a base in all costs. As noted earlier, any decision to make a part involving additional investment in facilities was based on the requirement that the investment earn an estimated gross return of at least 20%. The exception is the foundry, shown later in Table 47; the fact that the basic decision to make instead of buy an engine inherently involves a decision to have foundry machining operations, and engine assembly operations, with the rate of return in the foundry being unimportant in

comparison to the rate of return on the engine component of the whole tractor manufacturing facility.

2. A DETAILED MAKE-OR-BUY REVIEW WAS PERFORMED

Using parts lists and diagrams furnished by the manufacturers whose tractors were being studied, the analysts reviewed the components of the selected tractors. They identified the components to be purchased and those to be fabricated in a two-stage process: the identification of standard parts and standard purchased assemblies which would be purchased at all volumes, leaving a residue to be analyzed at a second stage for make-buy decisions. This second-level analysis involved determining the feasibility of manufacturing each item at the volumes selected, its potential contribution to profit, and the possible effect on assembly operations of purchase as opposed to in-house fabrication.

During this analysis and throughout the remainder of the study, the term "component" was used to identify the simplest items normally available for purchase as replacement parts. "Detail parts" was used to denote single items to be assembled. A generator, for example, was considered to be a component composed of detail parts.

The make-or-buy review consisted of determining and evaluating the answers to the following questions, which supplement the make-or-buy policies discussed in the previous section.

(1) What Is the Approximate Value of the Component and What Is Its Annual Cost at the Selected Volume? After discussion with the Commission, and based on statements by farm machinery companies during its public hearings, the approximate cost to them of individual components was estimated as one-third of the dealer

price for replacement parts that would be considered potentially to be "made" and one-half of the dealer price for parts that could probably be "purchased", in order to provide a starting point for the make-or-buy analysis. This cost was then extended by the number of components required per tractor unit to be assembled and by annual manufacturing volume. The resulting rough estimate of annual procurement cost was used to form the basis for determining the capital investment in facilities that could be justified to produce each group of components. When related to a preliminary calculation of the capital investment required to produce each group, it became obvious that certain types of operations could be supported, and others could not, at each volume level. The estimate also provided an indication of the significance of the make-or-buy decision. Therefore, components representing high annual costs received more detailed analysis.

(2) Can the Component Be Purchased "Off the Shelf" or Would the Vendor Have To Incur and Charge for Special Start-up Costs Equivalent to those of the Tractor Manufacturer? In many cases, the fact that a component can be purchased from vendor stock indicates almost automatically that it can be purchased at lower cost than it can be manufactured. By supplying more than one customer with identical or similar items, the vendor can spread facility and start-up costs over a large volume. While some items may require the absorption of special start-up costs, these may be less than the total start-up costs related to the component if it were made by the tractor manufacturer. If so, the item will generally be purchased. Examples of items normally purchased from vendor stock, with or without some modifications which may involve some start-up costs, are starters, standard gaskets, oil seals, and bearings.

(3) Does the Technology Required To Produce the Component Differ Widely from that Basic to Tractor Manufacture? Many components would be purchased because their manufacture would require entering fields that are unrelated to the metalworking technology which is basic to tractor production. Examples of such items are those made from glass, plastic, textiles, and rubber. Other items are produced from metal but require the use of particular expertise and equipment. Examples are nuts and bolts, springs, and electrical components.

(4) What Are the Problems and Approximate Cost of Transporting the Component to the Assembly Plant? In some instances, the difficulty and/or expense of packing and shipping a component would dictate that it be fabricated. A number of parts such as hydraulic lines are bulky in final form. To reduce shipping costs, they would be purchased in a semi-finished state and formed when they are needed.

Costs of shipping and protecting parts are factors that also dictate the location of certain assembly operations. Items such as engines, transmissions, steering gear, and hydraulic mechanisms would be assembled at the location at which their principal detail parts are machined, and only then delivered to a final assembly plant.

To sum up, make-or-buy analysis is both a complex and a continuing managerial function. The examination described previously was made without precise vendor prices. In actual practice, a number of items would probably be transferred from one category to the other to take advantage of available machine capacity or purchasing opportunities. In other cases, items would be manufactured simply to avoid the possibility of assembly stoppages caused by delivery failures. These transfers between the "make" and "buy" categories might affect the total cost of purchased components as much as 10%. However, the resultant reverse fluctuations in fabrication costs would minimize the net effect of the transfers on unit costs; therefore, very great precision is not critical to over-all costs in a preliminary analysis.

3. VOLUME AFFECTS THE PROPORTION OF COMPONENTS TO BE FABRICATED

At higher production levels, fabrication of additional components becomes economically feasible. This trend exists because of the opportunity to spread facility and setup costs over a larger output. Table 5 illustrates the trend towards fabricating components as volume increases.

An analysis of Appendix 2, on which Table 5 is founded, reveals that there are a large number of standard parts and purchased assemblies that would normally not be considered for manufacture by the tractor producer. These 1,365 parts (69% of the total number of parts) represent 41% of the outside purchase cost (at the 60,000-unit volume level) of the components required for tractor assembly. They are therefore treated in this analysis as a constant, removed from the make-buy decision process.

It is in relation to the remaining 608 parts (31% of the total number of parts) that decisions to make or buy are made. The summary data in Table 5 emphasize the importance of these parts to the company. At the price level for the 60,000-unit volume they represent 59% of the outside purchase cost of all the components required for tractor assembly. To the extent that the tractor manufacturer is able to reduce the costs of these parts by making them for less than it would cost him to buy them, his tractor manufacturing costs are correspondingly reduced.

TABLE 5

COMPARISON OF NUMBER AND COST* OF PURCHASED VS. MADE COMPONENTS

FOR ACTUAL MAKE-BUY MIX

	20,000 Units per Year				60,000 Units per Year				90,000 Units per Year			
	All Parts		Parts Capable of Being Made		All Parts		Parts Capable of Being Made		All Parts		Parts Capable of Being Made	
	% of Total Number	% of Total Cost	% of Total Number	% of Total Cost	% of Total Number	% of Total Cost	% of Total Number	% of Total Cost	% of Total Number	% of Total Cost	% of Total Number	% of Total Cost
Purchased Components												
Not subject to make-buy decision												
Standard parts	66	27			66	27			66	27		
Purchased assemblies	3	14			3	14			3	14		
Total	69	41			69	41			69	41		
Subject to make-buy decision**	13	16	43	27	9	12	29	9	2	1	7	2
Total purchased components	82	57	43	27	78	53	29	9	71	42	7	2
Made Components**	18	43	57	73	22	47	71	91	29	58	93	98
Total components	100	100	100	100	100	100	100	100	100	100	100	100

* Cost defined as purchased cost of component from vendors, not adjusted for volume requirements, at 60,000-unit volume level.

** These figures constitute the 608 components identified as being subject to make-buy analysis within the volume ranges examined.

Among these parts subject to the make-buy decision, the manufacturer makes 349 (in value 73% of their alternative outside purchase price for the group of 608 parts) at the 20,000-unit volume, 431 (in value 91% of their alternative outside purchase price) at the 60,000-unit volume, and 568 (in value 98% of their alternative outside purchase price) at the 90,000-unit volume. Only 40 parts, representing 2% of the value of the parts considered for possible manufacture, are in fact purchased at the 90,000-unit volume level.

4. VOLUME AFFECTS THE PRICE OF PURCHASED COMPONENTS

Volume price discounts result from economies of scale within the vendors' manufacturing plants. In addition, they result from savings in the vendor distribution costs. The costs of selling, packaging, and shipping are subject to economies of scale in much the same way as those of manufacturing functions.

From the analysts' extended experience in automotive and tractor manufacturing, it was estimated that the decrease in production from the base level of 60,000 units per year to 20,000 units would increase the price of purchased components by 7%. On the other hand, an increase from 60,000 units to 90,000 units was estimated to result in a price reduction of 3%. These projections were confirmed by estimates made independently by others who are responsible for volume purchasing of similar items in the industry. These cost changes for purchased items are an "average" only, with components manufactured outside in very high volumes being less affected by volume price changes than those where the tractor producer's requirements represent a more significant proportion of the outside manufacturer's production. They also represent the combined cost effects of differences in cost to the vendor to manufacture, store, pack, and ship at different volumes, and the change in purchasing power of the tractor producer as volume changes. Part of this change is represented by more purchasing staff at higher volumes, allowing for greater specialization.

5. PRICE DISCOUNTS AND MAKE-OR-BUY MIX OF ITEMS HAVE A COMBINED EFFECT ON THE COST OF PURCHASED COMPONENTS

The costs of purchased components at the selected volume levels were compared. To isolate the effect of volume, this comparison was made twice. First, purchased components costs were determined on the basis of a constant mix of purchased and fabricated components (constant make-buy mix). That is, costs were developed for all three levels, using the number of items to be purchased at the base production level of 60,000 units. Second, these costs were determined for the make-buy mix developed for each volume level (actual make-buy mix). The results of the second, or the "actual" mix, comparison were carried forward to the total unit cost projections presented in Chapter IX.

The results of both comparisons appear in Table 6 which summarizes data from Appendix 2.

The value of each category of parts bought at the different volume levels can be added to the costs of the same category of parts manufactured at that volume level. For example, the cost of the stampings bought at a particular volume level can be added to the cost of the stampings that can be economically made at that volume. The total of these two cost figures will give the cost to the manufacturer of all parts in the stamping category at that volume.

In this study, however, the cost of the parts "made" are the total (or average) for the three-tractor mix, while the cost of parts "purchased" are those shown in Appendix 2 relating to the

TABLE 6

COMPARISON OF PURCHASED COMPONENTS BETWEEN DIFFERENT MAKE-BUY MIXES

FOR THE THREE PRODUCTION VOLUMES

Purchased Components	Number of Parts in Actual Make-Buy Mix			Costs per Unit with the Constant Make-Buy Mix			Costs per Unit with the Actual Make-Buy Mix		
	20,000 Units per Year	60,000* Units per Year	90,000 Units per Year	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Not subject to make-buy decision									
Standard parts	1,311	1,311	1,311	$ 994	$ 929	$ 901	$ 994	$ 929	$ 901
Purchased assemblies	54	54	54	525	491	476	525	491	476
Total	1,365	1,365	1,365	$1,519	$1,420	$1,377	$1,519	$1,420	$1,377
Subject to make-buy decision									
Castings	45	25	-	$ 135	$ 126	$ 122	$ 212	$ 126	$ -
Stampings	75	61	19	155	145	141	157	145	10
Forgings	12	8	5	65	61	59	109	61	16
Steel bars	59	39	5	35	32	31	44	32	10
Tubing	65	43	11	45	42	41	62	42	5
Aluminum	3	1	-	2	2	2	20	2	-
Total	259	177	40	$ 437	$ 408	$ 396	$ 604	$ 408	$ 41
Total purchased components	1,624	1,542	1,405	$1,956	$1,828	$1,773	$2,123	$1,828	$1,418

* This number is used as basis for constant make-buy mix.

mid-range tractor only. Because the prices of the outside purchased items are for the mid-range model, they are likely to be more expensive than the average developed for the three-tractor mix. Thus, a small upward bias is thereby given in subsequent analyses to the average cost values for each process and the tractor manufacturing establishment as a whole.

With approximately 50% of total manufacturing costs represented by purchased parts and materials, the efficiency of the purchasing function of the tractor manufacturing plant is of major importance to the whole organization. The resources available and budgeted for this function at the different production volumes are shown in Table 7 (based on Appendix Table A36-1).

TABLE 7

MANPOWER ALLOCATED TO PURCHASING FUNCTION

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Managers	1	1	2
Supervisory and technical staff	4	10	14
Clerical staff	5	14	20
Total	10	25	36
Production volume relationship	1	3	4.5
Purchasing employees relationship	1	2.5	3.6

Between the 20,000 and 90,000 output levels, the number of persons allocated to this function increases 3.6 times, while the volume of production increases 4.5 times. On the other hand, as shown on Table 6, the value of purchased material per unit produced is greatest at the lowest production volume, declining from $2,123 at 20,000-unit volume to $1,418 at 90,000-unit volume. This decline of $705 or about one-third in purchased material costs occurs while the resources available to perform the purchasing function increase 3.6 times. If one compares the two trends, the purchasing function per dollar of purchased material in the finished tractor has increased more than five times between the lowest and highest volume. The consequent specialization results in better purchasing action being taken, and accounts, at least in part, for the 10% cost differential on purchased parts at the two volumes, identified in Appendix 2, Table A2-4.

IV

EXAMINATION OF COSTS OF CASTINGS (FOUNDRY COSTS)

Grey iron castings comprise a major part of the weight and between 14% and 16% of tractor manufacturing costs within the volume ranges studied. Molten metal is poured into prepared sand molds which give the desired shape to the casting formed when the metal solidifies. Foundry operations necessary to produce castings include molding, melting, core-making, and cleaning.

Molding involves the forming of sand molds that shape molten metal. Steel or wood replicas of the parts to be cast (patterns) are inserted into containers (flasks) filled with specially prepared sand to form impressions of the desired shape. To facilitate making the mold, the flask is divided into two halves (cope and drag sections).

In a modern foundry, the equipment for preparing molds, pouring metal, and separating castings from molding sand (shaking-out) is connected by conveyors to form continuous processing units called molding lines.

Melting is the heating of iron and various additives in preparation for pouring.

Core-making is the forming of shaped sand inserts in the molds which create voids in castings. The cores replace the metal that would otherwise fill their location, and are removed in the shaking-out and cleaning processes after the casting solidifies and cools.

Cleaning is the removal of sand and excess metal from castings. This operation is performed by blasting (bombarding with sand or steel shot) or grinding (with rotating abrasive wheels or disks).

Foundry operations were examined to determine their costs at the selected manufacturing volume levels. Foundry facilities represent large capital expenditures for equipment suitable to the production of a wide variety of metal shapes and sizes. Normally, given sufficient capacity, all castings would be fabricated. Exceptions would be items requiring the preparation of batches of different metals (malleable iron, for example) or requiring machining operations not found to be economical at low output levels. Typically, a captive foundry does not cast for outside machining, probably because of the cost of transportation and the difficulty of integrating a vendor (at arm's length) into an operation between two components of the same organization (foundry and assembly). These exceptions constitute the castings that would be purchased at the 20,000- and 60,000-unit levels.

Uniquely among the processes examined in the tractor manufacturing establishment, the foundry derives certain advantages from a type of continuous operation. While it does not operate fully around the clock, it must be able to pour metal as soon as the first shift of the day begins, even on Monday morning. Therefore, the holding furnaces must be tended to keep the metal melted on the last shift of the previous day ready for pouring, and the melting furnaces charged and brought up to their operational support role in the third shift period which is not otherwise utilized. A small number of maintenance and support personnel are therefore used on the third shift and on weekends in the foundry.

1. APPROPRIATE MOLDING LINE CONFIGURATIONS WERE DEVELOPED FOR THE SELECTED VOLUMES

A total of 149 castings were identified from the list of tractor components (Appendix 2). Of these, 46 standard and 12 optional parts were subjected to detailed analysis (Appendices 1 and 2). In selecting the high-value parts for analysis, attention was directed to their characteristics in terms of value, weight, design complexity, and usage per unit.

The analyzed parts range in size and complexity from that of the complicated transmission case to a simple bearing cap set, weighing 628 lbs. and 30 lbs., respectively. In total, they comprise 70% of the foundry cost and 85% of the weight of all castings. Engineers who have had extensive experience in foundry operations analyzed the manufacture of these parts in detail and used their facility and cost requirements to project the requirements for all castings. A list of the castings analyzed is included in Appendix 1.

(1) Molding Flask Dimensions Were Specified for the Analyzed Parts. In a foundry utilizing modern high-volume techniques, equipment must be designed with maximum commonality to ensure flexibility. The analysts were particularly concerned with keeping the number of different molding flasks to a minimum to reduce change-over time needed on molding lines. The number of flask sizes can range from that needed to provide a different size of flask for each part to one type of flask for all parts. Each of these extreme cases incurs penalties in either equipment cost or unit cost. Because of these penalties, optimum flask design, involving a trade-off between the two costs, is particularly important. In the design of molding flasks, the selected parts were sorted into groups, according to weight and size, and paper templates were prepared and used to develop optimum pattern arrangements. Molding flasks were then developed to accommodate the arrangements. The internal flask dimensions (sand strip dimensions) are shown in Table 8. The measurements indicated are

for length, width, and height for each of the cope and drag sections of the molding flask (the height shown would therefore be doubled for internal flask dimensions).

TABLE 8

MOLDING FLASK DIMENSIONS

	Length		Width		Height
			(Inches)		
Parts Analyzed					
Group I parts	44	x	36	x	15
Group II parts	44	x	28	x	10
Group III parts	30	x	30	x	8
Parts Not Analyzed					
Group A parts	30	x	30	x	8
Group B parts	30	x	30	x	8

(2) Molding Line Utilization Was Calculated and Line Configuration Designated. The types of molding lines selected and their utilization have a great effect on foundry costs. The analysts were required to make preliminary planning decisions based on judgment, to continue through to a workable plan, and then to adjust the preliminary decisions accordingly.

Operation planning sheets for the different types of molding lines were prepared. A sample sheet appears as Figure 4 and explanatory notes are shown in Figure 5. Based on these operation plans, the procedure followed in specifying molding lines was as follows:

-- Parts production requirements were calculated by multiplying usage per tractor by the number of units per year and adding scrap allowances.

FIGURE 4

PLANNING SHEET FOR FOUNDRY OPERATIONS

PROCESS ROUTING

PROJECT NO. SHEET 1 OF 2

Part Name	Sub Group	Model	Experimental Part No.	Production Part No.
CYLINDER BLOCK - MOLDING	ENGINE	80	----	1-2-15

Similar Part No.	Date Latest Engineering Change	Processed By	Volume	Checked By	Pieces Per Unit
-------		P. G.	60,000	C.H.G.	1

Material	Size of Stock Rough	Pieces Per mold	Weight Per Piece	Date
CAST IRON	----	1	680	4/30/68

Oper. No.	Description of Operation	Crew Size	Operation Std. Hrs.	Setup Hours	Equipment Description	Expenditures Expense	Expenditures Capital
10	Mix molding sand	3	.02000		3-mixers and delivery system		
20	Set drag flask on roll-in table (automatic)						
30	Make drag mold	1	.00667	.50	Pneumatic squeeze machine		
40	Roll drag mold over and set on mold conveyor				Drag and mold roll over and		
					set on station		
50	Automatic mold blow off and/or spray						
60A	Set six barrel cores in fixture	3	.02000		Core assembly fixture (4)		
60B	Set end core and water jacket core in fixture	2	.01333				
60C	Pick up core assembly with core setting fixture and set assembly						
	in drag mold	2	.01333		Core setting fixture (2)		
60D	Set chaplets as required	2	.01333				
70	Set cope flask on roll-in table (automatic)						
80	Make cope mold and inspect cope mold	2	.01333	.50	Pneumatic squeeze machine		
90	Place cope mold on drag mold (automatic				Transfer and closer		
100	Set weights on molds (automatic				Weight conveyor		
110	Pour iron into mold and check pouring temperature	4	.02667				
120	Break off sprue cup	1	.00667				
130	Remove weights from mold (automatic				Weight conveyor		
140	Strip cope from drag and move cope into idle station (automatic)				Cope strip and idle station		
150	Punch out sand				Punch out station		
160	Pick up and push drag flask into roll over				Automatic pick off machine		
170	Roll drag mold over - casting falls into shaker conveyor (automatic)				Roll over machine		

FIGURE 5

KEY TO PROCESS ROUTING ENTRIES

PROCESS ROUTING

PROJECT NO. Code Number Assigned to Project — SHEET This Sheet Number OF Pages in Total Routing

Part Name	Sub-Group	Model	Experimental Part No.	Production Part No.
Name of Component or Assembly	Classification by Functional Grouping	Production Identification	PART IDENTIFICATION	

Similar Part No.	Date Latest Engineering Change	Processed By	Volume	Checked By	Pieces Per Unit
-----	-------	Name of Analyst	60, 000	Name of Checker	Quantity per Tractor

Material	Size of Stock Rough	Pieces Per Bar or Sheet	Weight Per Piece	Date
Type of Raw Material	Dimensions of Raw Material	Number of parts in Multipiece Stock	Weight Incl. Scrap	Date Analysis was Made

Oper. No.	Description of Operation	Crew Size	Operation Std. Hrs.	Setup Hours	Equipment Description	Expenditures: Expense	Expenditures: Capital
Identification of Processing Operations					Identification of Processing Equipment Used on Each Operation		
	Notes	1	2	3		4	5

Notes

1 Number of workers required to perform this operation.

2 Number of hours per piece allowed to perform the operation on the machine. This figure times crew size equals the man-hours allowed for an operation.

3 Number of hours allowed per occurrence to set up jigs, fixtures, workplace layouts, or stock for this operation. Multiple-man crews are shown as /2.

4 Cost of jigs, fixtures, tools, and gauges (items which are expensed because they are expendable or subject to short-term obsolescence).

5 Cost of machinery and equipment (long-term capital assets).

-- Usage per tractor was taken from bills of materials. Scrap allowances were made at the rate of 2% for machining scrap and 5% for foundry scrap, based on industry experience. This scrap was to be remelted, thus reducing the costs of foundry materials.

-- Two basic types of molding lines were planned: cross-loop lines for the 44-inch flasks and in-line lines for the 30-inch flasks. The cross-loop line prepares the cope and drag sections of the mold simultaneously on parallel sections. This type of equipment is suitable for producing large castings but requires a higher capital expenditure than the in-line type which produces both sections on the same line. This type of equipment is suitable for producing smaller items but the requirements for double indexing the flasks past the molding stations curtails output severely if larger flasks are used. The principal advantages of the in-line equipment are that capital expenditures are lower and pattern change time is minimized. The difference between the two types is shown graphically in Figure 6.

-- Production rates in flasks per hour were established by adjusting the manufacturer's recommended attainable speed for his equipment for normal delays and interruptions in the foundry. Individual parts production rates were computed by multiplying line speed (expected flasks per hour) by the number of parts per flask (mold gang).

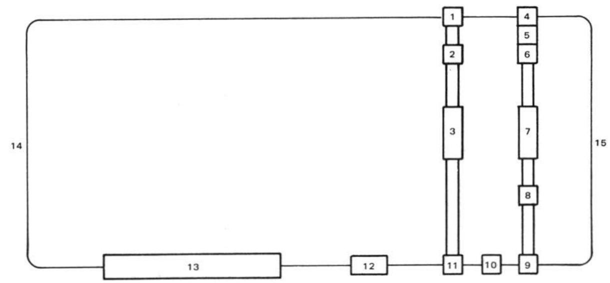
-- To determine the effect of setup time on line utilization, the analysts calculated molding line operating schedules and estimated the setups required. Operating schedule periods of two, four, eight, and 16 hours were used to take advantage of break periods and shift changes in minimizing production delays. Since a natural "break" occurred at each of these points of time, production runs of this length used normal downtime and interruptions of production to change from one part to another, so that the cost of change-overs was minimized. The production period selected for each item was that which would result in output that would most closely approximate a week's requirements.

-- Molding line loads were determined by calculating the necessary operating time and setup time for each analyzed part at each volume level. In addition, provisions were made for the casting of the parts not analyzed on the basis of estimated size, weight, and parts per flask, to establish the additional

FIGURE 6

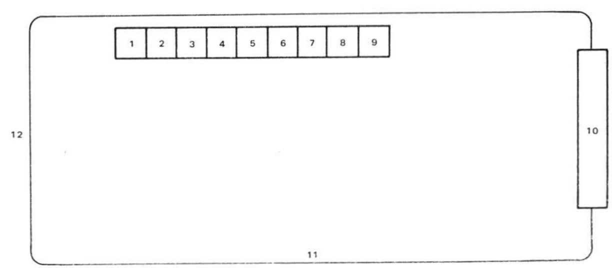
SCHEMATIC DIAGRAM OF MOLDING LINE CONFIGURATIONS

CROSS LOOP MOLDING SYSTEM



STATIONS
1. Lift cope mold off drag
2. Punch out sand
3. Make mold– (insert pattern in flask; fill with sand; jolt and squeeze sand over mold; remove pattern)
4. Pick drag mold off of molding car
5. Roll over
6. Punch out sand and casting
7. Make mold
8. Roll over
9. Set drag mold on molding car
10. Set cores
11. Set cope mold on drag mold
12. Set weights
13. Pour metal
14. Cool
15. Return molding cars

IN–LINE MOLDING SYSTEM



STATIONS
1. Transfer mold
2. Punch out sand and casting
3. Separate cope from drag
4. Make drag mold
5. Make cope mold
6. Turn drag mold over
7. Set cores
8. Set cope mold on drag mold
9. Transfer mold
10. Pour metal
11. Cool
12. Return molding cars

facilities, labour, and material needed. Equipment operation was planned at 80% of the utilization possible in a well-run plant. The use of an 80% planned utilization for this and all subsequent machinery planning provided the excess capacity discussed in Chapter I. Appendix 3 is a compilation of the calculated line utilization at each volume level.

-- Molding line loads were calculated on the basis of a standard "mix" of parts being required. To the extent that actual production requirements differed from the standard "mix", substantial cost penalties could be incurred.

-- Projected molding line utilization was reviewed to determine the changes required to optimize machine utilization. Table 9 presents the required number of molding lines and their anticipated utilization. As indicated in this table, line utilization at the 20,000-unit level is rather low. This condition is largely caused by the fact that one line of each type is required and that the required volume is below the resulting capacity. In actual practice, a continuing effort would be made to utilize this capacity. One approach would be to produce batches of malleable iron components that exceed the requirements of the assumed general scheduling cycle. Another would be to re-examine decisions to purchase components made from machined castings.

-- The drop in the utilization of the in-line machine from 93% in the constant make-buy mix to 70% in the actual make-buy mix shown in Table 9 is explained by the removal of the economic justification for making certain specialty iron castings (e.g. nodular iron, or malleable iron) at the lower volume, coupled with the change from "make" to "buy" for certain machining operations on castings which, as a corollary, indicate that the casting itself would also be bought.

-- The 109% utilization indicated in Table 9 at the 90,000-unit level results from the use of 80% of practical operating capacity as the planned capacity for calculating utilization. Levels as much as 25% above planned capacity could be achieved by additional staffing or hours of operation.

(3) Related Molding Equipment Was Designated. After the number of molding lines required was determined, planning was directed to subsidiary equipment. This equipment includes molding line conveyors, casting cooling conveyors, molding sand

TABLE 9

MOLDING LINE REQUIREMENTS AND UTILIZATION

	20,000 Units per Year		60,000 Units per Year		90,000 Units per Year	
	Lines Required	Percentage Utilized	Lines Required	Percentage Utilized	Lines Required	Percentage Utilized
Constant Make-Buy Mix						
Cross-loop machine	1	60	2	77	2	109
In-line machine	1	93	3	84	4	87
Total lines required	2		5		6	
Actual Make-Buy Mix						
Cross-loop machine	1	60	2	77	2	109
In-line machine	1	70	3	84	5	82
Total lines required	2		5		7	

systems, and flask shake-out conveyors. Molding line production rates and machinery dimensions were converted into time and distance parameters to determine conveyor requirements. Molding sand requirements were calculated and the appropriate sand-handling system was specified for each line.

2. MELT SHOP REQUIREMENTS WERE DETERMINED

Production requirements in the molding area establish the basis for output projections for other operations which are themselves inputs to the molding area. Melting facility requirements were investigated in the following manner:

(1) Basic Iron Requirements Were Determined. A number of factors make up basic iron requirements. These include the weight of finished castings; metal to be removed in machining operations; metal for pouring access, connections, and vents (gates, runners, and sprues); and allowance for metal to replace castings scrapped in machining and founding operations.

These factors were calculated for all analyzed parts. Estimates were also prepared for all parts not analyzed. Table 10 summarizes the annual iron requirements for the planned foundry operations.

(2) Hourly Metal Requirements Were Estimated. Because of the variety of parts being cast on the same molding equipment, requirements for iron melting equipment cannot be based solely on average tons of metal required per hour. Hourly metal requirements vary with the weight of the parts being run and their production rates. The scheduling of certain parts is critical because they have hourly tonnage requirements considerably higher than the average. Provisions must be made to meet peak demands for molten metal when these critical parts are run -- that is, molten metal must be available to produce these items throughout

TABLE 10

TOTAL ANNUAL IRON REQUIREMENTS

	Tons per Unit	Constant Make-Buy Mix: 20,000 Units per Year	Constant Make-Buy Mix: 60,000 Units per Year	Constant Make-Buy Mix: 90,000 Units per Year	Actual Make-Buy Mix: 20,000 Units per Year	Actual Make-Buy Mix: 60,000 Units per Year	Actual Make-Buy Mix: 90,000 Units per Year
		(Thousands of tons)					
Net casting weight	2.3	46	138	207	44	138	213
Gross melting weight	3.3	66	198	297	64	198	303

their scheduled production period. Appendix 4 lists hourly iron requirements for all analyzed parts. Two listings are shown: (i) on the basis of the maximum tons per hour the parts would require during periods of continuous molding operation, and (ii) the anticipated tons per hour used for planning purposes.

Having determined the wide range between average tonnage and peak tonnage, the analysts proceeded to identify and specify equipment to meet anticipated maximum demands with a minimum of investment. The use of melting furnaces and holding furnaces was planned to take advantage of melting during slack periods to meet peak demands. Capacity was provided to cast more than a week's requirement of the heaviest part, the transmission case, during one continuous production period. This is the combined result of a requirement for approximately 200 transmission cases a week for the medium sized tractor at the 20,000-unit volume level and the foundry molding line capacity of 300 transmission cases in the minimum cycling period of two hours. Scheduling restrictions would require that a light part be run on the other line(s) and that the holding furnace(s) be full at the start of the run. Table 11 illustrates the differences among average hourly iron requirements calculated on an annual basis, the maximum demand that would result from running the heaviest parts simultaneously, and the capacity required to meet anticipated surges in demand.

(3) Furnaces Were Selected for a Duplexing System of Melting and Holding. Electric arc furnaces were selected for melting, and electric induction furnaces for holding. Arc furnaces create heat through use of electrodes immersed in the metal. Induction furnaces use electric coils that are built into the crucible walls. Both types are used to take advantage of their different efficiencies in the temperature ranges involved.

TABLE 11

HOURLY IRON REQUIREMENTS

	Actual Make-Buy Mix		
	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
		(Tons)	
Average hourly requirement	22	65	97
Maximum hourly requirement	142	293	325
Specified hourly melting capacity	60	150	210
Specified holding capacity	100	400	600

Electric furnaces were used rather than coke-fired cupolas because of their lower operating cost and because emission control equipment necessary to prevent air pollution with coke-fired cupolas would increase both the initial investment and operating costs of cupolas. Electric melting furnaces have the further advantage of being able to accept for remelting all iron and steel scrap, without baling, because they do not have an induced draft, as would be the case with coke-fired cupolas.

Table 12 lists the number of furnaces required for each of the selected volume levels. The designated melting furnaces have the capacity to pour 30 tons of iron per hour. Holding furnaces would have a capacity of 100 tons each. Foundry equipment configurations were developed in consultation with a leading manufacturer of foundry equipment. Larger furnace sizes would have produced little cost advantage and would extend the time required to melt a charge.

TABLE 12

FURNACE REQUIREMENTS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Melting furnaces	2	5	7
Holding furnaces	1	4	6
Total furnaces	3	9	13

(4) Other Melt Shop Equipment Was Designated. Equipment connected with the furnaces was specified for each production volume level. These items include furnace charging equipment, hot metal carrying equipment, and pouring equipment. Although furnace charging equipment is based on the number of melting furnaces projected, the other subsidiary furnace equipment is based on the number of molding lines being served.

3. CORE-MAKING OPERATIONS WERE EXAMINED

Cores are used in casting tractor parts to form cylinder bores and water jackets in cylinder blocks as well as to form holes in cast gears or wheels. The proper use of cores reduces or eliminates certain machining operations. This examination deals with the core-making equipment necessary at the selected volume levels.

(1) Basic Core Requirements Were Determined. The analyzed parts were again examined to determine the type and size of required cores. The cores required were categorized by size and by the number produced during each cycle of the core-making machine. Machine-hour requirements were calculated by determining, for each category, the expected net production per

machine-hour, and by dividing this figure into the projected annual output requirements for that category. Cores are fragile and scrap losses of 17% were included in the requirements projections. Core requirements were estimated for the castings not analyzed, from an examination of their number and type. Additional machine-hour allowances were made to provide for these requirements. Machine-hour requirements were converted into the number of machines needed.

The core-making machinery designated consists of small machines with a maximum dimension capacity of 20 inches and large machines to produce cores that exceed this dimension. Both sizes are of the "hotbox" type -- that is, the cores are formed and baked on the same machine rather than being transferred to ovens. This procedure provides a lower cost and more flexible operation than the older technique of using separate ovens.

Projected core machinery requirements are summarized in Table 13 (see Appendix 5 for the detailed calculations).

TABLE 13

CORE MACHINE REQUIREMENTS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Constant Make-Buy Mix			
Large core machines	6	15	22
Small core machines	1	4	5
Actual Make-Buy Mix			
Large core machines	6	15	25
Small core machines	1	4	6

Other core room equipment was planned around the core machines. This equipment includes core sand system, core dip drying oven, and core assembly fixtures (at molding lines). This equipment is listed in Appendix 6 along with equipment for the other foundry operations.

4. <u>EQUIPMENT REQUIREMENTS FOR CLEANING CASTINGS WERE DETERMINED</u>

Cleaning castings involves not only removal of molding sand and core sand from the casting, but removal of excess metal deposited in the molding process. Excess metal often is formed in molding as a result of accidental core shifts, flask separation, and sand washout. Various kinds of equipment are used to perform these cleaning operations on different parts.

After the flask shake-out has separated the castings from the molding sand, cleaning would be done in abrasive blast machines. Blast machines bombard the castings with metal shot to remove sand and loose metal. Small parts are tumbled in barrel-shaped containers during blasting and large parts are moved past the shot nozzles by conveyors.

Metal flash is removed by chipping with pneumatic or hand chisels on conveyors. Other excess metal is removed by grinding. Grinding by hand is performed on small parts at a stationary, two-wheel grinder. On large parts, portable grinders are used at the conveyors. Automatic grinding machines would be incorporated into the process conveyors at the 90,000-unit level.

5. <u>RAW MATERIAL COSTS WERE DETERMINED</u>

Foundry raw material costs were determined on the basis of expected usage per gross ton of metal poured. This cost, which accounts for furnace charging materials, additives, and molding materials, amounted to \$55 per ton, based on Chicago-Detroit prices, net of the tractor plant's own scrap. Appendix 7 details the materials involved and Table 14 summarizes annual costs. No reduction in prices of foundry raw materials would be expected at high volumes, because carload quantities of the major items are required at all production levels.

TABLE 14

ANNUAL TONNAGE AND COST OF FOUNDRY MATERIALS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Constant Make-Buy Mix			
Gross tonnage (thousands)	66	198	297
Annual cost (thousands of U.S. dollars)	$3,630	$10,890	$16,335
Number of parts	124	124	124
Actual Make-Buy Mix			
Gross tonnage (thousands)	64	198	303
Annual cost (thousands of U.S. dollars)	$3,520	$10,890	$16,665
Number of parts	104	124	149

6. CAPITAL REQUIREMENTS FOR FOUNDRY OPERATIONS WERE DETERMINED

The investment required to provide foundry facilities was computed in the following manner:

(1) Requirements for Machinery and Equipment Were Estimated. A list was prepared of all the machines and equipment specified for each department. This list was enlarged to include other equipment, such as that needed for emission control, pattern making, utilities, and other services. Necessary materials handling equipment was also included.

Estimates of equipment costs were developed in two ways. Equipment manufacturers were contacted concerning certain items, and the analysts used cost data from actual installations for other items. These estimates were extended by the requirements at each volume to arrive at a total cost. Similar calculations were made for pattern equipment after requirements were determined. Appendix 6 is the tabulation of foundry equipment and its cost.

A sizable portion of the capital cost has been allocated for exhaust emission control to reduce air pollution. This expenditure amounts to $6.5 million at the 90,000-unit volume level, or approximately 17% of total equipment cost. Emission control standards which the plant would satisfy were based on current Michigan requirements.

(2) Floor Space Requirements and Building Costs Were Projected. Total floor space requirements for the foundry were calculated by adding those for production areas, pattern shop, maintenance, inspection, and laboratory functions. To this total was added space for access aisles, in-process storage of parts, and auxiliary equipment. Construction cost was determined by extending the area by current building cost data. These calculations are summarized in Table 15 and are detailed in Appendix 8.

(3) Working Inventories Were Estimated. The quantities of raw materials, work in process, and finished castings ready for machining or assembly that would be on hand were estimated. These quantities were determined in terms of weekly output on the basis of the anticipated scheduling cycles. These materials were assigned values, depending on their state of fabrication. Raw materials were carried at cost; semifinished components (work in process) at materials plus labour cost; and finished castings at full fabrication cost. Appendix 9 is a tabulation of inventory costs.

TABLE 15

TOTAL CAPITAL REQUIREMENTS FOR FOUNDRY

(Thousands of U. S. dollars)

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20, 000 Units per Year	60, 000 Units per Year	90, 000 Units per Year	20, 000 Units per Year	60, 000 Units per Year	90, 000 Units per Year
Machinery and equipment	$11, 504	$26, 866	$36, 881	$11, 504	$26, 866	$38, 361
Building costs	7, 900	16, 800	22, 925	7, 900	16, 800	23, 800
Inventory	802	2, 293	3, 401	776	2, 293	3, 497
Total capital required for "permanent" facilities	$20, 206	$45, 959	$63, 207	$20, 180	$45, 959	$65, 658
Additional average investment for tooling (taken as 50% of initial investment)	1, 270	1, 320	1, 395	1, 210	1, 320	1, 470
Total capital requirements	$21, 476	$47, 279	$64, 602	$21, 390	$47, 279	$67, 128

(4) Total Capital Requirements Were Determined. The investment capital requirements for foundry operations were calculated by totalling the investments in machinery, equipment, and plant facilities. Table 15 summarizes capital requirements. During this and subsequent examinations special purpose tooling was not considered a "permanent" capital requirement. In effect, such items as patterns (stamping dies, machining jigs, and assembly fixtures) were considered to be "quick write-off" items rather than capital assets. These items represent invested funds and must be considered when examining plant profitability. (For calculations related to corporate profits, see Chapter IX and Appendix 50.)

7. FACILITY AND CAPITAL COSTS WERE CALCULATED

Costs of depreciation, taxes, and insurance on machinery and equipment were calculated. A depreciation rate of 5% on buildings and of 10% on equipment was applied on a straight-line basis. Special purpose tooling, such as pattern- and core-making equipment, was amortized at the rate of 33% per year to reflect obsolescence caused by styling or technological changes.

Capital costs were calculated to represent the cost of money invested in machinery, equipment, buildings, and inventories. An accounting cost of 7.5% was used to cover a level of appropriate interest charges on these investments. (For calculations related to corporate profits see Appendix 50 and Chapter IX.) To reflect the effect of depreciation on operating costs, the investment in buildings and equipment was calculated at 80% of original cost, indicating the effect of depreciation charges on the operating statement. This figure is an approximation of the investment represented by the specified facilities after two to four years of operation. The investment in inventories was based on the calculations described earlier. Expendable supplies and hand tools were excluded from inventory as having been expensed at time of purchase, but an appropriate amount for annual expenses as part of foundry operating expenses is shown in Appendix 12.

8. LABOUR COSTS WERE DETERMINED

The manpower required to operate the foundry was determined and payroll costs estimated.

(1) Manpower Requirements Were Developed. Modern foundry operations are essentially continuous manufacturing processes, requiring manning similar to that of assembly lines with defined work stations and job assignments. Basic process-planning sheets written for molding, core-making, and cleaning departments describe the operations in these departments in sequence (see Appendix 10). Molding line station planning was prescribed on the planning sheets. For other operations, machine manning was estimated from machine crew size and expected output per machine.

Estimates of labour productivity in the foundry and other production departments assume the following conditions:

-- Employees would be trained in efficient methods through a comprehensive and continuing program of instruction.

-- Employees would exert a level of effort consistent with a comprehensive system of measured work assignments.

-- Effective supervisory and production control practices would minimize operating delays and interruptions.

-- Preventive maintenance techniques would eliminate most mechanical breakdowns.

(2) Manning Tables Were Prepared. The number of men required at the different production volume levels is shown in the manning tables in Table 16. These staffing projections have two bases:

TABLE 16

FOUNDRY MANNING REQUIREMENTS

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Direct Labour						
Foundry workers	184	511	734	169	511	800
Inspectors	12	36	58	12	36	66
Absentee and trainee replacements	22	61	88	20	61	96
Total direct labour	218	608	880	201	608	962
Indirect Labour						
Foundry workers	52	120	177	51	120	188
Inspectors	4	6	8	4	6	8
Material handlers	6	15	25	6	15	28
Maintenance personnel	31	81	120	31	81	120
Total indirect labour	93	222	330	92	222	344
Support Staff						
Supervisory staff	20	49	71	19	49	77
Clerical and technical staff	9	17	22	9	17	22
Total support staff	29	66	93	28	66	99
Total foundry manning requirements	340	896	1,303	321	896	1,405

- -- Calculations for molding and core-making staffing were made by extending the machine and line loads developed earlier by the required crew size and by converting these hours into manpower on the basis of 1,920 hours per man per year. This number is a standard industry projection and allows for hours not worked, due to holidays and vacations. Details of these calculations are presented in Appendix 11.
- -- Manpower for the other operations was based on machine staffing and expected hours of operation.

Additional manpower was allowed in direct labour operations to provide for absenteeism, training of new employees, and other operating losses. These allowances totalled 10% and were based on the following assumptions related to foundry operations and typical of the foundry industry:

- -- Losses from absenteeism would average 7.5% of the direct labour force.
- -- Training of new employees and other operating losses would require 5% over-staffing. These excess personnel would be only 50% utilized.

These factors are based on the analysts' knowledge of current experience data in several automotive and tractor plants.

(3) Annual Payroll Costs Were Calculated. On the basis of Western Ontario wage rate data provided by the Commission, the analysts calculated the total payroll costs required in the foundry. These calculations, shown in Appendix Table A11-6, included a 30% fringe benefit allowance for pensions, vacations, holidays, insurance, workmen's compensation costs, unemployment insurance costs, etc.

9. FOUNDRY OPERATING EXPENSES WERE PROJECTED

Budgets were prepared for annual purchases of such items as: refractories and electrodes; perishable tools, hand tools, and gauges; abrasive supplies; replacement parts for patterns and fixtures; contract repairs and calibrations; miscellaneous factory supplies; miscellaneous clerical supplies; rework and repairs; utilities; heat; and sundry expenses.

These estimated budgets were based on the analysts' prior experience in developing actual budgets for foundry operations. A comparison of the budgeted amount for each production level shows a range of $874,000 at the 20,000-unit level to $3,594,000 at the 90,000 level for a constant mix of parts. Detailed budgets are to be found in Appendix 12.

10. TOTAL FOUNDRY COSTS WERE COMPILED

All of the cost factors examined in the foregoing sections were tabulated to determine annual total costs for the selected volume levels. These cost factors are displayed in a pro forma statement of operating costs in Appendix 13. Unit costs were determined by dividing annual totals by unit volume. Table 17 summarizes the results of this analysis.

The data presented under the "Memo" heading in Table 17 provide further insight into foundry operating costs at different volumes. The allocation of the support costs (set out in Chapter IX and taken from Table 38) gives more correct costs of foundry operations, considering the foundry as a separate establishment.

Castings from the foundry either go through a machining operation or go directly to the assembly plant. The last part of Table 17 divides the value of the castings between the two categories. Through this method of analysis, it is possible to show a cost on Table 27 for foundry castings entering the machining operations, an input which is made rather than purchased.

The constant mix analysis indicated sizable savings in fixed costs as volume rises. Savings are also realized in labour and operating costs, but to a lesser degree. The principal savings result from better utilization of the large fixed investment in plant and machinery. The variable analysis indicates that anticipated changes in make-buy mix of components have only a slight effect on foundry costs.

TABLE 17

SUMMARY OF FOUNDRY COSTS PER UNIT

(U. S. dollars)

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs						
Materials	$182	$182	$182	$176	$182	$185
Labour	113	100	98	106	100	105
Operating expenses	57	52	50	55	52	52
Variable costs	$352	$334	$330	$337	$334	$342
Fixed Costs						
Facility costs (including tooling costs)	$168	$109	$ 97	$166	$109	$101
Capital costs	61	47	42	61	47	45
Fixed costs	$229	$156	$139	$227	$156	$146
Total unit costs	$581	$490	$469	$564	$490	$488
Memo:						
Add allocated support costs (Table 39)	$ 99	$ 81	$ 73	$ 99	$ 81	$ 73
Total foundry unit costs for average tractor	$680	$571	$542	$663	$571	$561
Total number of parts cast 1/	124	124	124	104	124	149
Number of parts used directly as castings, no machining 2/	25	25	25	25	25	25
Cost of parts used directly as castings, no machining	($154)	($130)	($125)	($154)	($130)	($125)
Remaining parts requiring machining	99	99	99	79	99	124
Cost of remaining parts requiring machining	$526	$441	$417	$509	$441	$436

See notes on next page.

Notes to Table 17:

1/ From Appendix 2.

2/ From Appendix Table A1-1, 25 parts shown as "Castings, No Machining", Purchase Price $143. For these parts, no change in make-buy decision is shown in second footnote to Appendix Table A1-1 at 20,000-unit volume; all castings (149) made at 90,000-unit volume (Table A2-1). Therefore, these 25 parts can be considered as a constant group, always cast at all volumes. Estimated price on Table A1-1 reduced to cost at 60,000-unit volume by deducting assumed 10 per cent profit in purchase price. Cost adjusted to 20,000-unit volume by 7 per cent increase, to 90,000-unit volume by 3 per cent decrease.

V

EXAMINATION OF THE COSTS OF STAMPINGS

The fabrication of stampings, parts formed from sheet metal, constitutes between 4% and 6% of total manufacturing costs within the volume ranges studied. These parts are formed by placing the metal to be shaped between mating dies and forcing the dies together. Auxiliary operations include shearing and blanking (cutting metal to size), welding (joining two or more parts), cleaning, and painting. The effect of volume changes on these fabrication costs was examined.

1. STAMPING OPERATIONS FOR SELECTED COMPONENTS WERE ANALYZED IN DETAIL

Of the 222 sheet metal components, 23 were selected for in-depth analysis. These components ranged in weight from .05 pounds (grille frame channel) to 68 pounds (side-frame). They are formed from stock varying in thickness from 22 gauge sheet to 3/8-inch plate. Tooling varied from simple to moderately complex. The fabrication and subassembly operations required to produce the selected components were examined in detail. This examination provided the basis for determining per-unit stamping costs.

Analysts with extensive experience in stamping processes planned the manufacture of the selected components. They incorporated in these plans the most modern technology compatible with the selected volumes. The resulting planning sheets specify the operations to be performed, machinery and equipment required, tooling, material specification, and labour standards for both setting up and operating the presses and other equipment (based on experience or standard data).

This analysis was performed first for the 60,000-unit volume. Changes in the processing of parts required for volumes of 20,000, 30,000, and 90,000 units were then identified and used to determine appropriate cost changes for the other volumes.

A sample planning sheet appears as Figure 7. Explanatory notes were shown on Figure 5.

2. MATERIAL COSTS WERE EVALUATED

Raw material costs for stampings were determined for analyzed parts by calculating a design weight. This design weight is the total of the part-blank plus allowances for waste and rejects. "Rejects" include pieces that cannot be used because of poor metal or malfunctions during the stamping process. For additional parts, the analysts calculated material requirements from estimated weights. These calculations are based on the assumptions that efficient utilization would be made of "off fall" or large pieces remaining after the part-blank has been cut from the original metal sheets. The calculated weights were extended by current material prices that reflected the effect of volume changes. Table 18 summarizes these costs and Appendix 14 shows the details of this examination.

TABLE 18

NUMBER OF PARTS AND TOTAL ANNUAL STAMPING MATERIALS COSTS

	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Constant Make-Buy Mix				
Annual cost (thousands of U. S. dollars)	$1,500	$2,190	$4,200	$6,111
Number of parts to be made per unit	161		161	161
Actual Make-Buy Mix				
Annual cost (thousands of U. S. dollars)	$1,485	$2,190	$4,200	$9,270
Number of parts to be made per unit	142		161	203

FIGURE 7

PLANNING SHEET FOR STAMPING

PROCESS ROUTING

PROJECT NO. 3751-001-2 — SHEET 1 OF 1

Part Name	Sub Group	Model	Experimental Part No.	Production Part No.
Cover-Timing Gear	Engine	80		1-3-3C1

Similar Part No.	Date Latest Engineering Change	Processed By	Volume	Checked By	Pieces Per Unit
		D. C.		C. H. G.	1

Material	Size of Stock Rough	Pieces Per Bar or Sheet	Weight Per Piece	Date
13 Ga. (.0897) hrs. P and O Drawing Quality	38 x 112	16	6.9 pounds	3-18-68

Oper. No.	Description of Operation	Crew Size	Operation Std. Hrs.	Setup Hours	Equipment Description	Expenditures: Expense	Expenditures: Capital
10	Shear to 19 x 112.	1	.0002	.25/1	700 10' Capacity Shear Power	-------	
20	Cut off and First Draw.	2	.0049	2.00/2	703 300 Ton SS Press 36"x35" with Cushion	3,000	
30	Trim outside and pierce 13 flange holes and 1 shaft opening.	1	.0040	2.00/1	704 110 Ton OBI Press	3,200	
40	Pierce and extrude (2) 1/4" diameter holes and form flanged shaft hole (hit bottom on shaft hole for flatness on flange and surrounding area).	1	.0040	2.00/2	724 150 Ton SS Press 33"x33"	1,800	
50	Form outer flange. (Hit bottom to flatten mating face.)	1	.0040	2.00/2	724 150 Ton SS Press	2,200	
60	Inspect.				Bench	400	
70	Wash and store.	2	.0072	------	705 Washing Machine	-----	
	Notes	1	2	3		4	5

Notes:

1 Number of workers required to perform this operation.

2 Number of hours per piece allowed to perform the operation on the machine. This figure times crew size equals the man-hours allowed for the operation.

3 Number of hours allowed per occurrence to set up jigs, fixtures, workplace layouts, or stock for this operation. Multiple man crews are shown by the number to the right of the /, e. g., /2 for 2 men.

4 Cost of jigs, fixtures, tools and gauges (items which are expensed because they are expendable or subject to short-term obsolescence).

5 Cost of machinery and equipment (long-term capital assets).

3. MATERIALS HANDLING AND PARTS FEEDING TECHNIQUES INTERNAL TO THE STAMPING OPERATIONS WERE DEVELOPED

Materials handling and feeding equipment required to move components between operations was specified. This equipment was designed to minimize total costs, paying particular attention to the relationship between labour costs and machine utilization. Stock tables, portable turning devices, monorails, and roller conveyors were combined into the optimum handling system. The specified equipment was included in the equipment list for each volume.

4. TOOLING SPECIFICATIONS WERE DEVELOPED

The analysts specified the dies to be used for each part analyzed. A design life of three years, representing industry practice, was assumed in determining the necessary die life.

Quality and design requirements were held constant at each output level. That is, components were not redesigned to simplify tooling or reduce operating costs at lower volumes, although some evidence exists that such action is typical in the industry. Some opportunities exist for reducing tooling costs and equipment investment by using general purpose sheet metal equipment instead of high production stamping presses. For instance, the use of rail type presses in place of high production stamping presses would enable the fabricator to use brake press tooling as well as some limited stamping press tooling. These opportunities were not explored because stamping facility costs are less than 0.5% of total unit costs, at all volume levels.

Tooling selections were made on the basis of anticipated operating costs during the three-year period. In most cases, the tooling required to produce 20,000 units per year is adequate and appropriate for use at the 90,000-unit level -- that is, the minimum setup to fabricate a particular part would usually meet the needs of all the levels examined. In fact, the tooling investment of $1,370,000 required at the 90,000-volume level is only $107,000 more than that needed to process the same parts at the 20,000 level.

The range of annual volumes explored does not provide opportunity for cost savings that would justify sophisticated tooling or stamping equipment. Volumes in the range of 200,000 to 300,000 units would present opportunities that would make possible the use of such items as hardened steel dies and automatic feeding and ejection equipment. This analysis did not indicate a major breaking point in the downward trend of stamping costs. Rather, new labour-saving equipment would be acquired as the result of a number of individual decisions that would be made as volume increased over a wide range. The cost per unit would decrease at a gradual rate as the costs of labour and capital equipment became a smaller portion of total cost.

Material costs per unit of production show only small reduction as volume increases, as indicated in Figure 8 and Table 19. The costs projected beyond the 90,000-unit volume level should be considered as general extrapolations only.

TABLE 19

PROJECTION OF STAMPING COSTS

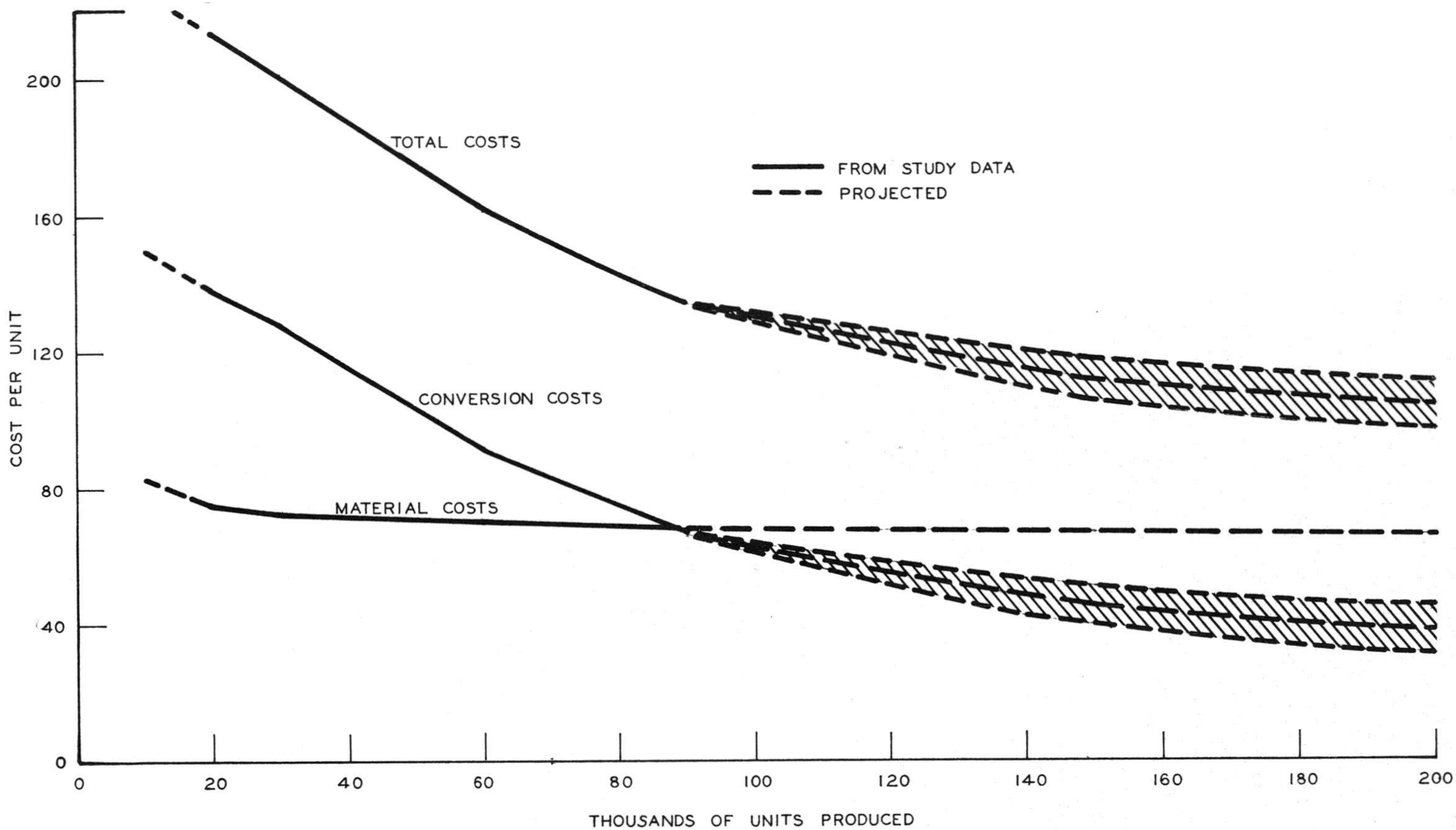
CONSTANT MAKE-BUY MIX

(U.S. dollars)

	Range Analyzed				Range Projected	
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year	150,000 Units per Year	200,000 Units per Year
Unit material costs	$ 75	$ 73	$ 70	$ 68	$ 67	$ 66
Conversion costs	138	128	91	66	45	38
Total costs	$213	$201	$161	$134	$112	$104

FIGURE 8

PROJECTION OF STAMPING COSTS AT HIGHER VOLUMES



Unit "conversion costs" (the costs of labour and plant facilities to make the sheet steel into stampings) decline much more rapidly than material costs -- from $138 to $66 across the range analyzed (Table 22), from 181% of materials costs to 97% of materials costs. These conversion costs can be expected to decline at a decreasing rate and are projected by the analysts to the 200,000-unit volume level in Figure 8. Material costs are shown as declining to $66 and conversion costs to $38, or 58% of materials costs. Total stamping costs would therefore probably decline from $213 per unit at a volume of 20,000 units to $104 at 200,000 units.

The Commission also asked that some broad, generalized consideration be given to the cost of stampings used in combine manufacture, to allow certain conclusions of this study to be extrapolated to cover these costs. Stampings are a higher proportion of total costs of combines than of tractors, but two other dimensions have also changed: the stamping is less complex and therefore easier to make (typically a flat plane with holes pierced at precise locations, capable of being made with steel rule dies and punches) and the volume of production is greatly reduced (10,000 for a typical North American combine plant, with a range between 500 and 20,000). One can only postulate that material costs will rise at lower volumes, and that conversion costs in relation to material costs will be lower than for tractor stampings because of the relative simplicity of the parts.

The two effects are shown in Figure 9 in terms of relative numbers. The curve representing material costs is shown as relatively flat, while that representing conversion costs is much more strongly affected by volume changes and thus curves more sharply upward as volume falls. The two relative cost curves can be added together, if an arbitrary assumption about the ratio of conversion costs to material costs is made at some specific output level. In the first case (shown as Conversion Costs I), they are shown as 75% of material costs at the 10,000-unit volume; in the second case (shown as Conversion Costs II), they are considered as 150% of material costs at this same level.

As shown on Figure 9 and Table 20, the resulting Total Cost Curves I and II give significantly different cost approximations. Curve I is one-third below Curve II at the 500-unit level and about one-fifth lower at the 20,000-unit level. The difference in the decline of Total Costs from the lowest to the highest volume points on the two Total Cost Curves, however, is relatively much less. Total Cost Curve I declines 37% while Total Cost Curve II declines 42%. Economies of scale are naturally greater for Total Cost Curve II, which gives double the weight to conversion costs which, as noted earlier, decline more rapidly as volume increases. These very broad cost estimates are shown as relative numbers on Table 20, giving a rough approximation of economies of scale in the manufacture of combine stampings. Thus, a set of stampings for a combine is likely to be between 50% and 75% more costly at an annual volume of 500 units than at a volume of 20,000 units per year.

5. <u>SUMMARIES OF MACHINE AND EQUIPMENT REQUIREMENTS WERE DEVELOPED</u>

Summary lists of required machinery and equipment were developed on the basis of the operation standards specified earlier. The following paragraphs describe the steps taken to develop the summaries.

(1) Component Production Scheduling Concepts Were Developed. Most stampings would be produced in batches of a predetermined size. The batch sizes determine the number of die changes to be

FIGURE 9

PROJECTION OF COMBINE STAMPING COSTS

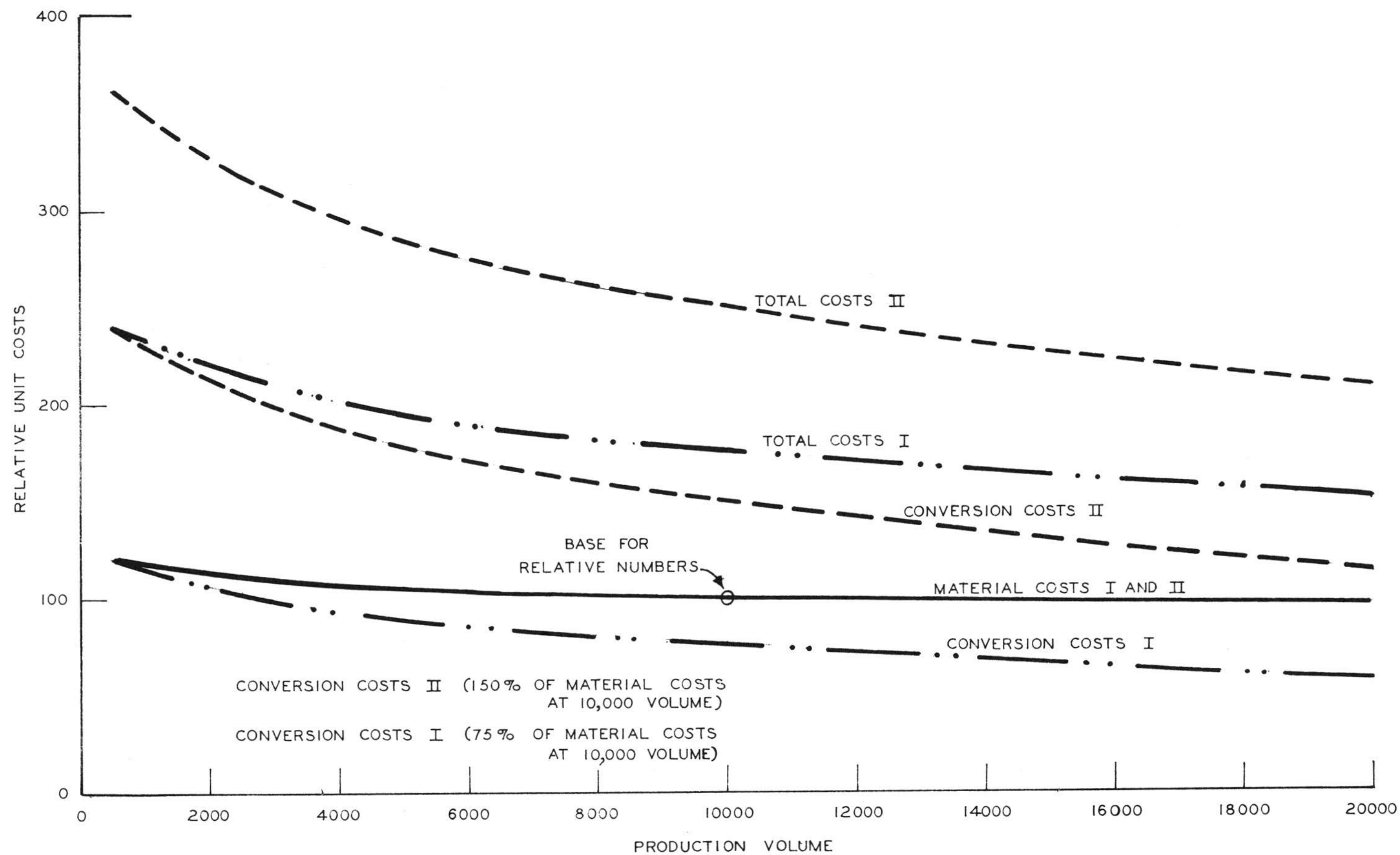


TABLE 20

COMBINE STAMPING COSTS EXPRESSED IN RELATIVE NUMBER VALUES

AT APPROPRIATE VOLUMES

	500 Units per Year	2,500 Units per Year	5,000 Units per Year	10,000 Units per Year	20,000 Units per Year
Cost Curves I (Conversion/material ratio 75% at 10,000 units)					
Relative Costs (Material costs at 10,000 units as 100)					
Material costs	120	112	106	100	96
Conversion costs	120	103	89	75	56
Total costs	240	215	195	175	152
Relative Costs Index (20,000 units as 100)					
Material Costs Index	125	117	110	104	100
Conversion Costs Index	214	184	159	134	100
Total Costs Index	158	141	128	115	100
Cost Curves II (Conversion/material ratio 150% at 10,000 units)					
Relative Costs (Material costs at 10,000 units as 100)					
Material costs	120	112	106	100	96
Conversion costs	240	206	178	150	112
Total costs	360	318	284	250	208
Relative Costs Index (20,000 units as 100)					
Material Costs Index	125	117	110	104	100
Conversion Costs Index	214	184	159	134	100
Total Costs Index	173	153	137	120	100

made and, therefore, affect total machine utilization. Batch sizes of one, two, and four weeks' usage were examined to determine the effect on setups and storage requirements. In most cases, the selected batch size was a week's production requirements. In actual practice, batch size would be optimized by more precise scheduling techniques. As mentioned earlier, the potential cost reductions from more sophisticated scheduling are not significant to this study.

(2) Automated Data Processing Techniques Were Used to Project Machine-Hour Requirements. Each press and piece of equipment was assigned an identifying machine code. This code and the labour standards for setup and operation were recorded on punched cards. Cards were prepared for each component examined. These cards were sorted and the time standards extended mechanically to produce total machine time requirements for each type.

(3) The Necessary Presses and Auxiliary Equipment Were Specified. Machine-hour requirements were used to determine the number and type of presses and other equipment needed. The analysts based their decisions on the assumption that normal annual operation would cover 80% of a possible two-shift operation. Equipment time was provided for fabricating the components that were not analyzed in detail.

The machine-hour requirements were reviewed to evaluate the practicality of combining the hourly requirements for two presses into one press. For example, work that would be done on a 110-ton press at the 60,000-unit volume level was transferred to a 150-ton press at the 20,000-unit volume level. The effect of such a transfer is to use a larger and more expensive press than is necessary to make the part, thus increasing its cost, but at the same time fully utilizing the 150-ton press which otherwise would be underutilized, thus keeping total costs as low as possible.

Additional equipment was provided for the parts not analyzed by increasing the general purpose machines in proportion to the relationship between the estimated manufacturing costs of the analyzed and unanalyzed parts. This extrapolation could result in an error of as much as 15% either way in the equipment investment estimate for these parts. In view of the small portion of stamping costs represented by these parts (not more than 31% of total stamping costs) and the fact that the error would be present at each volume level, the potential error was considered insignificant.

The result of this analysis was the specification for each volume of a wide range of press sizes suitable for the production of large- and medium-sized stampings. The equipment lists developed during this analysis appear in Appendix 15. Figure 10 shows two presses in use in the stamping plant.

6. CAPITAL REQUIREMENTS FOR STAMPING OPERATIONS WERE DEVELOPED

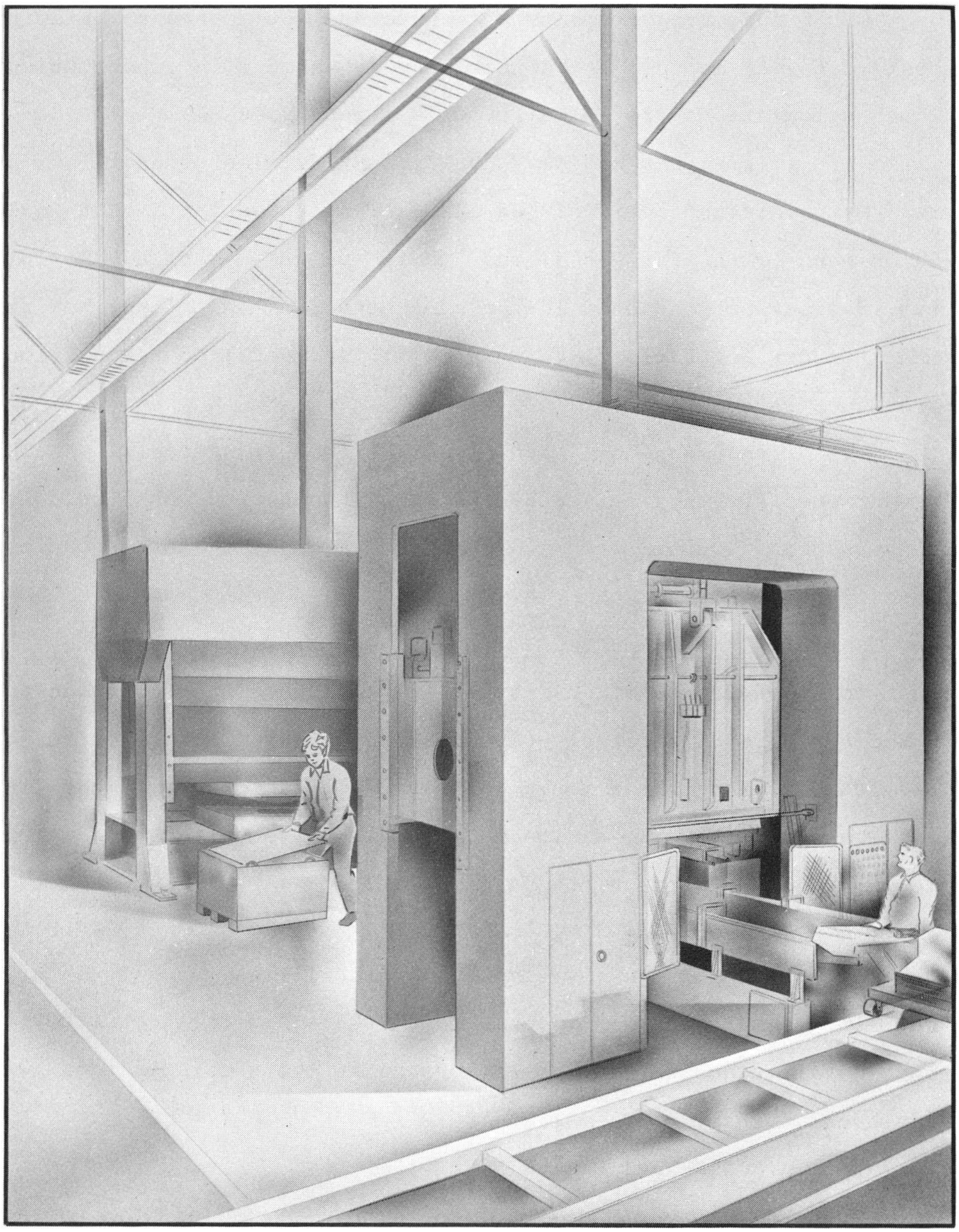
The investment required to provide the presses, equipment, and building space needed in the stamping areas was computed as follows:

(1) The Investment in Machinery and Equipment Was Computed. This investment for each volume level was computed by extending the equipment list developed earlier by the appropriate prices. The prices used represent the total cost of purchase, delivery, and installation. Appendix 15 contains the result of this computation.

(2) Floor Space and Building Cost Requirements Were Determined. The floor space to be occupied by the required machinery was computed. This figure was increased to provide

FIGURE 10

TYPICAL STAMPING EQUIPMENT



space for access aisles, in-process inventory, and ancillary operations. Supervisory and staff offices were also included.

Floor space requirements were extended by current building cost data to calculate the necessary investment in construction. These calculations are to be found in Appendix 16.

(3) Working Inventories Were Estimated. The quantities of raw materials and semifinished and finished components that would be on hand were estimated and their value determined. This examination was conducted in the same manner as that described for the foundry operations in Chapter IV, and detailed calculations are shown in Appendix 17.

(4) Total Capital Requirements Were Estimated. The investments for machinery and equipment inventories and building construction were combined to determine the total capital investment required, shown in Table 21.

7. FACILITY AND CAPITAL COSTS WERE CALCULATED

Costs of depreciation, taxes, and insurance on facilities and equipment were calculated. Depreciation rates of 5% for buildings and 10% for presses and equipment were applied on a straight-line basis. Tooling was assigned a design life of three years and depreciated at the rate of 33% per year.

In addition, an interest cost of 7.5% of net invested capital was calculated for the investment in facilities and inventory. Facility investment was calculated at 80% of initial construction and installation costs. The rationale for these calculations was reviewed in Chapter IV.

8. LABOUR COSTS WERE DETERMINED

The annual payroll costs of the manpower needed to operate and maintain the stamping equipment were estimated.

TABLE 21

TOTAL CAPITAL REQUIREMENTS FOR STAMPING PLANT

(Thousands of U. S. dollars)

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Machinery and equipment	$1,449	$1,640	$3,153	$3,846	$1,426	$1,640	$3,153	$ 5,634
Building costs	1,050	1,180	2,205	2,552	1,050	1,180	2,205	3,439
Inventory	308	435	820	1,181	304	435	820	1,772
Total capital required for "permanent" facilities	$2,807	$3,255	$6,178	$7,579	$2,780	$3,255	$6,178	$10,845
Additional average investment for tooling (taken as 50% of initial investment)	632	632	632	685	619	633	633	727
Total capital requirements	$3,439	$3,887	$6,810	$8,264	$3,399	$3,888	$6,811	$11,572

(1) Total Man-Hour Requirements Were Developed. The analysts made total man-hour estimates on the basis of the labour standards developed during the detailed planning. Additional man-hours were added for fabricating those parts not analyzed in detail. Allowances were made to provide for absenteeism, training of new employees, and other operating losses. These allowances were based on:

-- Average absenteeism of 12% with 67% effective utilization of replacement personnel (4% loss).

-- An annual turnover of 10% and a three-month non-productive training period (2.5% loss).

-- Other losses for tardiness, power failures, accidents, etc. amounting to 1%.

The total 7.5% allowance was applied to direct labour staffing. This allowance agrees with the analysts' experience in stamping and machining operations in well-managed plants.

(2) Manning Tables Were Prepared. Detailed manning tables were developed for the stamping operations at the selected production volume levels. These tables specify the number of men needed in each labour category. Man-hour projections were converted into the number of men needed, based on 1,920 hours per man per year. Details of these calculations appear in Appendix 18. Table 22 presents a summary comparison of the manning tables for the stamping operations.

(3) Annual Payroll Costs Were Calculated. Based on Western Ontario wage rate data provided by the Commission, the analysts calculated the total payroll costs required in the stamping plant. These calculations, shown in Table A18-4, included a 30% fringe benefit allowance for pensions, vacations, holidays, insurance, workmen's compensation costs, unemployment insurance costs, etc.

TABLE 22

STAMPING PLANT MANNING REQUIREMENTS

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Direct Labour								
Machine operators	61	89	177	266	60	89	177	391
Setup men	28	28	35	35	27	28	35	39
Inspectors	2	3	6	8	2	3	6	12
Absentee and trainee replacements	7	10	18	25	7	10	18	36
Total direct labour	98	130	236	334	96	130	236	478
Indirect Labour								
Material handlers	4	6	10	13	4	6	10	16
Inspectors	4	5	8	10	4	5	8	11
Maintenance personnel	12	15	20	26	10	15	20	42
Total indirect labour	20	26	38	49	18	26	38	69
Support Staff								
Supervisory staff	6	8	15	21	6	8	15	28
Clerical staff	7	9	12	16	7	9	12	18
Total support staff	13	17	27	37	13	17	27	46
Total stamping plant manning requirements	131	173	301	420	127	173	301	593

9. OTHER OPERATING EXPENSES WERE ESTIMATED

The analysts prepared annual budgets for such items as lubricants and compounds; perishable tools, welding and abrasive supplies, hand tools, and gauges; replacement parts for dies and fixtures; contract repairs and calibrations; factory supplies; clerical supplies; rework and repair; utilities; heat; and sundry expenses and contingencies.

These estimated budgets were based on the analysts' prior experience in developing actual budgets for similar operations.

TABLE 23

SUMMARY OF STAMPING COSTS PER UNIT

(U. S. dollars)

	Constant Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs				
Materials	$ 75	$ 73	$ 70	$ 68
Labour	43	38	33	31
Operating expenses	14	12	10	10
Variable costs	$132	$123	$113	$109
Fixed Costs				
Tooling amortization	$ 21	$ 14	$ 7	$ 5
Other facility costs	16	12	12	9
Capital costs	8	7	6	5
Fixed costs	$ 45	$ 33	$ 25	$ 19
Total unit cost	$177	$156	$138	$128
Memo:				
Add cost of purchased stampings for medium-HP tractor (Adjustment factors, Table A2-3)	$155		$145	$141
Add allocated support costs (Table 39)	35		23	26
Approximation for total costs of made and bought stamped parts requirements	$367		$306	$295

These expenses varied in direct proportion from $155,000 at 20,000 units per year to $735,500 at the 90,000-unit level. A detailed comparison of these costs appears in Appendix 19.

10. TOTAL STAMPING COSTS WERE COMPILED

The cost factors developed earlier were combined into projections of the total cost of stamping operations per unit at the selected volume levels. The annual totals for all of the cost factors examined above were tabulated at each level. A detailed pro forma statement from which these data were drawn is contained in Appendix 20. Unit costs were obtained by dividing the annual totals by the unit volume. Table 23 summarizes this analysis.

TABLE 23

(Concluded)

	Actual Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs				
Materials	$ 74	$ 73	$ 70	$103
Labour	43	38	33	45
Operating expenses	13	12	10	13
Variable costs	$130	$123	$113	$161
Fixed Costs				
Tooling amortization	$ 21	$ 14	$ 7	$ 5
Other facility costs	16	12	12	13
Capital costs	8	7	6	8
Fixed costs	$ 45	$ 33	$ 25	$ 26
Total unit cost	$175	$156	$138	$187
Memo:				
Add cost of purchased stampings for medium-HP tractor (Adjustment factors, Table A2-3)	$157		$145	$ 10
Add allocated support costs (Table 39)	35		23	26
Approximation for total costs of made and bought stamped parts requirements	$367		$306	$223

Economies of scale in stamping operations are illustrated by the constant make-or-buy mix comparison. Since the required tooling investment increases only slightly from 20,000 to 90,000 units, a very significant reduction in cost is realized in tooling amortization per unit. Additional savings are projected from increased use of facilities, spreading of setup labour cost over more units, volume purchases of materials and supplies, and decreased costs of invested capital per unit.

The actual make-buy mix comparison among the three volumes shows the cost impact of the larger number of stamped parts to be fabricated at the 90,000-unit level. Additional materials, labour and facilities would be required to accommodate the larger number of different parts that would be stamped.

When the cost of the purchased stampings for the medium horsepower tractor is added, however, for each volume level, the savings in purchasing costs more than offset the increase in manufacturing costs. The combined effect is shown at the bottom of Table 23, along with an appropriate allocation of the support costs set out in detail in Chapter VIII. When all costs of the requirement for stamped parts, made or purchased, for the tractor plant are included, at least in proxy form, the cost per tractor drops from $367 at the 20,000-unit volume to $223 at the 90,000-unit volume, a difference of $144 a tractor.

VI

EXAMINATION OF COSTS OF MACHINED COMPONENTS

The costs of machining fabricated components constitute between 12% and 19% of the total manufacturing cost within the volume range studied. The examination described in the following paragraphs was made to determine the effect of volume changes on these costs.

1. THE MACHINING OF SELECTED HIGH VALUE COMPONENTS WAS PLANNED IN DETAIL

The fabricated parts that require machining operations, such as milling, turning, boring, gear hobbing, and drilling, plus related operations such as heat treating and hardening processes, were identified and 45 high-value items were selected for detailed analysis. This group included parts made from castings, purchased forgings, and such materials as steel bar stock. They range in complexity from that of the engine block, which requires more than 20 machining operations, to that of a front hub cover, which requires only two. Their estimated manufacturing cost is about 58% of the total cost for all machined parts.

(1) Comprehensive Operation Planning Sheets Were Developed. Manufacturing engineers with extensive experience in metalworking planned the machining for the selected components. They incorporated the most modern technology available into detailed operation planning sheets. These sheets specify each operation to be performed; the machinery and equipment required; feeds, speeds, and tooling; and labour standards for both setting up and operating the machinery.

This analysis was performed first at the 60,000-unit volume level. The resulting planning sheets were then reviewed for changes that would be required at the other levels. In most cases, the changes consisted of adding to or reducing facilities rather than altering the technique or process itself. Figure 11 shows one of the operation planning sheets for a cylinder block.

(2) Conveyorized Machining Lines Were Developed. Special purpose machining lines were specified for such large, complex components as the cylinder block, crankshaft, cylinder head and transmission case. These lines provide for mechanized transfer of components through sequential machining stations. They reduce the labour spent on materials movement between operations and increase machine utilization. Comparatively little setup time is required and work flows from one machine to the next without the delays inherent in a series of batched operations. Such lines were economically justified for these major components even at the lowest level of 20,000 units.

The cylinder block line offers an example of the sophisticated combinations of machines and handling equipment required for a sequential machining line. At the 90,000-unit level, this line is designed to produce finished blocks from raw castings at the rate of 30% per hour. It is composed of 115 special purpose machine tools and 16 transfer devices. Part of the drilling operations is picture in Figure 12.

Increasing utilization of the investment in special purpose machine tools is one way of achieving economies from increased manufacturing scale. For example, the lines requiring minimum investment, developed for the 20,000-unit level, are capable of

FIGURE 11

PLANNING SHEET FOR MACHINING

PROCESS ROUTING

PROJECT NO. 3751-001 SHEET 1 OF 6

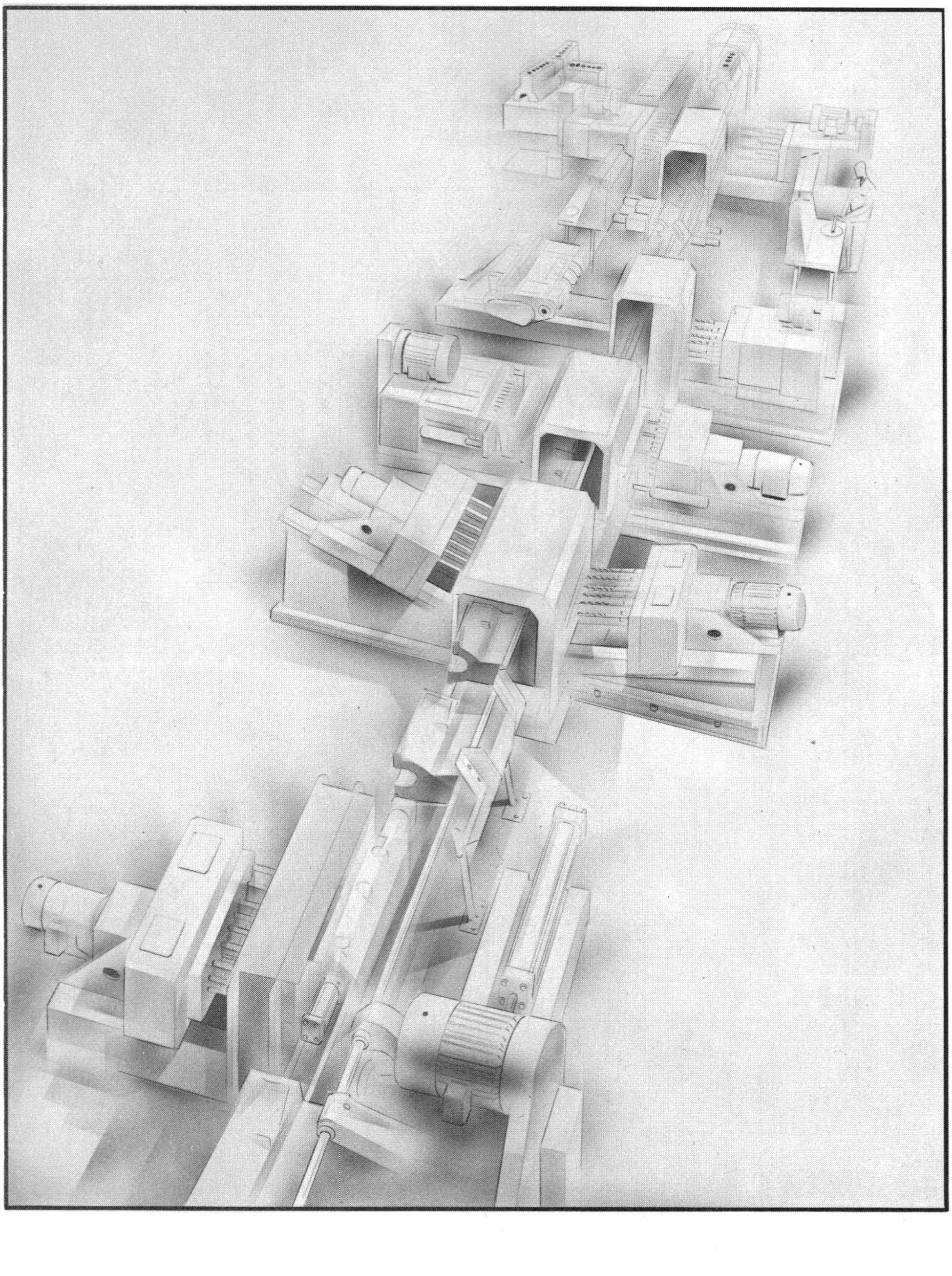
Part Name	Sub Group	Model	Experimental Part No.	Production Part No.
Cylinder Block	Engine	80		1-2-15

Similar Part No.	Date Latest Engineering Change	Processed By	Volume	Checked By	Pieces Per Unit
		R. F. B.		C. D.	1

Material	Size of Stock Rough	Pieces Per Bar or Sheet	Weight Per Piece	Date
Cast Iron I			500	2-22-68

Oper. No.	Description of Operation	Crew Size	Operation Std. Hrs.	Setup Hours 1/	Equipment Description	Expenditures Expense	Expenditures Capital
	20,000	25	.1025	75	15 Man Setup Crew		3,500,000
	60,000	43	.0513	120	23 Man Setup Crew		4,500,000
	90,000	46	.0342	126	25 Man Setup Crew		4,825,000
					Line #402		
10	Qualify cylinder bores, push rods, water passages and side and	1			Probe type inspection (trunnion		
	rear walls. Invert, inspect bearing fits, pan rails, and crankshaft				type mount) and twin hook		
	line. Qualify (4) points for locators				mono rail roll over unit		
20	Station 1-Broach pan rail				Horizontal Broach		
	Station 2-Broach bearing fits and half round for bearing				Horizontal Broach		
	Station 3-Index to 90°				Index Fixture		
	Station 4-Broach locator notch				Horizontal Broach		
	Station 5-Rough mill top (475SFM x 65 RPM x 39"/minute)				Fixed Spindle Mill 10" Hi		
					Fd Cutter		
	Station 6-Finish broach top station				Horizontal Broach		
30	Station 1-Drill (2) 47/64" holes (80SFM-408 x.010")	1			Single Spindle Drill		
	(2) 31/64" holes (80SFM-610 x.008")						
	For explanations see Figure 5.						
	1/ Setup hours required per occurrence.						

FIGURE 12
CYLINDER BLOCK DRILLING STATION



producing about 30,000 units annually. Unit costs were therefore examined at this higher level to evaluate the resulting facilities cost reduction.

The number of lines required does not change at higher volume levels. Rather, machines are added to increase the capacity of bottleneck operations. In other words, the cost of a machining line normally consists of a substantial initial investment which is increased by a series of variable increments as output demands increase. This concept is illustrated by the schematic drawing of the block line in Appendix 21, which shows the increments to be added at the higher volume levels.

2. COSTS OF RAW MATERIALS WERE EVALUATED

A substantial number of machined components are fabricated from purchased forgings, bar stock, aluminum, tube, and similar material rather than from castings. The cost of these items was determined by segregating the items produced from each type of material, estimating annual usage, and extending that usage by current prices. Anticipated price variations due to volume were also considered. Appendix 22 presents the details of this examination, and Table 24 shows the material costs on an annual basis.

TABLE 24

TOTAL ANNUAL MACHINING MATERIALS COST, EXCLUSIVE OF CASTINGS

(Thousands of U. S. dollars)

	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Constant Make-Buy Mix				
Annual cost	$3,100	$4,560	$8,700	$12,690
Actual Make-Buy Mix				
Annual cost	$2,235	$4,560	$8,700	$17,490

3. MACHINERY REQUIREMENTS WERE DETERMINED

The operating standards developed during the detailed planning were extended to determine the number and types of machines required. The following paragraphs describe the steps involved in this analysis.

(1) Component Production Scheduling Cycles Were Developed. Most machined components would be produced in batches of a predetermined size. The batch sizes determine the number of mechanical setup changes to be made and thereby affect the ability to use machines effectively. The batching concepts explored involve producing one or more weeks' requirements before changing setups. In most cases the requirements for a week's assembly operations were selected as batch size. This examination was made on a generalized basis to determine approximate setup frequencies. In actual practice, more precise machine scheduling techniques would be used to select optimum batch size. These techniques might reduce machine setup costs as much as 5%. However, inventory carrying costs would be increased by larger batches and would probably limit net savings to no more than $10 per unit. As mentioned earlier, the potential cost reductions from more sophisticated scheduling are not significant to this study.

(2) Machine-Hour Requirements Were Developed. For each analyzed component, a punched card was prepared to record the particular machines required and their setup and operating standards. These cards were sorted and extended to develop machine-hour requirements.

(3) The Necessary Machinery and Equipment Were Specified. Machine-hour requirements were used to determine the number and type of machines needed. This examination followed the general approach, described in Chapter V, for determining stamping machinery requirements. Provision was also made for materials

handling and other auxiliary operations within the machining area. The equipment lists developed during this examination and supporting calculations are to be found in Appendix 23.

4. CAPITAL REQUIREMENTS FOR MACHINING FACILITIES WERE DETERMINED

The investment required to provide the facilities needed for the machining operations was computed as follows:

(1) The Investment in Machinery and Equipment Was Determined. This investment was computed by extending the equipment lists developed earlier by the appropriate prices. The prices used represent the total cost of purchase, delivery, and installation. Where special tooling (jig, fixtures, etc.) is required, these costs have also been estimated. Cutting inserts, bits, and similar items were considered to be supply items. Appendix 23 also contains the results of this analysis.

(2) Floor Space and Building Cost Requirements Were Projected. Total floor space requirements for the machining departments were determined by increasing the space to be occupied by the machinery and equipment to provide for access aisles, working inventories, and auxiliary production. Floor space requirements were extended by current building cost data to determine the necessary investment in construction. Appendix 24 contains these calculations.

(3) Working Inventories Were Estimated. The quantities of raw materials and semifinished and finished components that would be on hand were estimated and their value determined. This examination was conducted in the same manner as that described for the foundry operations in Chapter IV, and detailed calculations of inventory values are shown in Appendix 25.

(4) Total Capital Requirements Were Estimated. The investments for machinery and equipment were combined with those for building construction to determine the total capital investment required, as shown in Table 25.

TABLE 25

TOTAL CAPITAL REQUIREMENTS FOR MACHINING OPERATIONS

(Thousands of U. S. dollars)

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Machinery and equipment	$17,540	$23,020	$40,352	$58,150	$15,705	$23,020	$40,352	$69,690
Building costs	1,340	1,772	3,276	4,515	1,181	1,772	3,276	5,471
Inventory	617	892	1,686	2,426	479	892	1,686	3,197
Total capital required for "permanent" facilities	$19,497	$25,684	$45,314	$65,091	$17,365	$25,684	$45,314	$78,358
Additional average investment for tooling (taken as 50% of initial investment)	152	201	376	536	136	201	376	657
Total capital requirements	$19,649	$25,885	$45,690	$65,627	$17,501	$25,885	$45,690	$79,015

5. DEPRECIATION AND CAPITAL COSTS WERE CALCULATED

Depreciation rates of 5% for building and 10% for machinery and equipment were applied on a straight-line basis. Special purpose tooling was amortized at the rate of 33% per year to reflect obsolescence caused by styling or technological changes.

6. LABOUR COSTS WERE DETERMINED

The annual payroll costs of the manpower needed to operate and maintain the metalworking machinery and supporting equipment were estimated.

(1) Total Man-Hour Requirements Were Developed. The analysts made man-hour estimates based on the labour standards developed during the detailed planning. Additional man-hours were included for machining those parts not analyzed in detail. Allowances were made to provide for absenteeism, training of new employees, and other operating losses on the same basis as that used during the stamping examination.

(2) Manning Tables Were Prepared. The manning table, Table 26, specifies the number of men required at the selected volume levels. These staffing projections are based on the man-hour estimates developed earlier. These estimates were converted into personnel requirements on the basis of 1,920 hours per man per year. Details of these calculations appear in Appendix 26.

(3) Annual Payroll Costs Were Calculated. Using wage rate and fringe benefit data provided by the Commission, the analysts calculated the total payroll costs required in the machining areas. These calculations are also to be found in Appendix 26.

7. OTHER OPERATING EXPENSES WERE PROJECTED

The analysts prepared annual budgets for such items as: lubricants and coolants; cutting inserts, bits, and other perishable tools, hand tools, and gauges; replacement parts for jigs and fixtures; contract repairs and calibrations;

TABLE 26

MACHINING OPERATIONS MANNING REQUIREMENTS

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Direct Labour								
Machine operators	387	569	1,080	1,470	328	569	1,080	1,760
Line setup men	14	14	27	30	14	14	27	30
Inspectors	20	27	55	81	15	27	55	100
Absentee and trainee replacements	34	48	91	127	29	48	91	152
Total direct labour	455	658	1,253	1,708	386	658	1,253	2,042
Indirect Labour								
Material handlers	12	14	26	38	11	14	26	46
Inspectors	4	6	12	18	4	6	12	24
Maintenance personnel	39	54	101	139	33	54	101	180
Total indirect labour	55	74	139	195	48	74	139	250
Support Staff								
Supervisory staff	19	27	48	69	18	27	48	88
Clerical staff	7	9	16	24	7	9	16	32
Total support staff	26	36	64	93	25	36	64	120
Total manning requirements in machining operations	536	768	1,456	1,996	459	768	1,456	2,412

miscellaneous factory supplies; miscellaneous clerical supplies; rework and repairs; utilities; heat; and sundry expenses and contingencies. These estimated budgets were based on the analysts' prior experience in developing actual budgets for similar operations. Appendix 27 presents a comparison of these budgets at the selected levels.

8. TOTAL MACHINING COSTS WERE COMPILED

The annual totals for all of the cost factors examined previously were tabulated for the selected volume levels. A pro forma statement of operating costs appears in Appendix 28. Unit costs were obtained by dividing annual totals by unit volume. Table 27 presents the results of this summary analysis.

The constant-mix analysis indicates that substantial savings in labour and facilities costs will result from volume increases. The savings in labour result from spreading setup and indirect staffing costs over more units and the facility savings from better utilization of fixed investment in plant and machinery.

The effect of increasing output from 20,000 to 30,000 units is to reduce facilities costs by $18 per unit at the constant make-buy mix, primarily as a result of better utilization of the machining lines. Additional facility cost savings result from further volume increases because facility addition (particularly machining line equipment) are not required in proportion to the additional volume.

The lowest cost make-buy mix among the three volumes shows the cost impact of the larger number of machined parts to be made at the 90,000-unit level. Machining costs per tractor increase by 20% between the 60,000- and 90,000-unit levels, because more types of parts would be machined at the higher level. Therefore additional materials, labour, and facilities would be required.

TABLE 27

SUMMARY OF MACHINING COSTS PER UNIT

(U.S. dollars)

	Constant Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs				
Materials	$ 155	$ 152	$ 145	$ 141
Labour	186	179	170	155
Operating expenses	37	34	32	32
Variable costs	$ 378	$ 365	$ 347	$ 328
Fixed Costs				
Facility costs (incl. tooling costs)	$ 144	$ 126	$ 110	$ 106
Capital costs	59	52	45	44
Fixed costs	$ 203	$ 178	$ 155	$ 150
Total unit cost	$ 581	$ 543	$ 502	$ 478
Memo:				
Add cost of portion of foundry output for average tractor identified as requiring machining (Table 17)	$ 526		$ 441	$ 417
Add cost of purchased machined parts for medium-HP tractor (Adjustment factors, Table A2-3)	282		263	255
Add allocated support costs for average tractor (Table 39)	132		123	119
Approximation for total costs of made and bought machined parts requirements	$1,521		$1,329	$1,269

TABLE 27

(Concluded)

	Actual Make-Buy Mix			
	20,000 Units per Year	30,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs				
Materials	$ 112	$ 152	$ 145	$ 194
Labour	159	179	170	186
Operating expenses	32	34	32	41
Variable costs	$ 303	$ 365	$ 347	$ 421
Fixed Costs				
Facility costs (incl. tooling costs)	$ 128	$ 126	$ 110	$ 127
Capital costs	53	52	45	53
Fixed costs	$ 181	$ 178	$ 155	$ 180
Total unit cost	$ 484	$ 543	$ 502	$ 601
Memo:				
Add cost of portion of foundry output for average tractor identified as requiring machining (Table 17)	$ 509		$ 441	$ 436
Add cost of purchased machined parts for medium-HP tractor (Table A2-4)	447		263	31
Add allocated support costs for average tractor (Table 39)	132		123	119
Approximation for total costs of made and bought machined parts requirements	$1,572		$1,329	$1,187

Below the "Memo" heading in Table 27, however, three additional items of cost are shown -- the cost of the portion of the foundry output requiring machining, the cost of the outside purchased machined parts, and an appropriate allocation of the support costs identified in Chapter VIII. While the cost of machined parts made in-house increases from $484 to $601 between the 20,000- and 90,000-unit volumes, the cost of purchased machined parts for the medium horsepower tractor declines from $447 to $31. The combination of all costs relating the total requirement of machined parts needed for tractor assembly declines, at least in this proxy form, from $1,573 to $1,187, a reduction of $386 per tractor.

Comparison of the constant and actual make-buy mix portions of Table 27 reveals that make-buy changes resulted in increased unit costs of $51 at the 20,000-unit level. This increase results from the decision to purchase at that level a number of engine parts that might be fabricated at a slightly lower cost. These parts -- the flywheel, cylinder liners, pistons, and connecting rods, for example -- would require a substantial expenditure for facilities and start-up costs, as well as the development of special manufacturing expertise. The small potential cost advantage did not appear to justify fabricating these "borderline" components.

VII

EXAMINATION OF ASSEMBLY COSTS

Assembly is the last productive step in tractor manufacture and constitutes about 5% of total tractor costs within the volume range studied. The operations required to assemble components in the subassemblies and into complete tractors were examined. These operations include fitting and securing the components of such major subassemblies as the engine and transmission (normally performed immediately after machining operations and usually considered part of the engine or transmission building activity) and building up the tractor frame, attaching components and subassemblies to it, operational testing, final painting, and attaching optional equipment and trim (normally called the final assembly operations). Assembly operations were costed, however, without specific breakdown for individual subassemblies such as engines, and transmissions and axles. The assembly of the engine, transmission, and completed tractor would take place on conveyorized assembly lines. Other subassemblies would be built up at bench stations along the main lines or on short subsidiary lines.

1. ASSEMBLY OPERATIONS WERE PLANNED IN DETAIL

Operation planning sheets were prepared for each standard subassembly and for the completed tractor itself. The analysts specified the components to be assembled, the steps to be performed, labour standards, and necessary equipment and tools. The first of the tractor assembly planning sheets is shown as Figure 13. Figures 14 and 15 depict the engine assembly and transmission assembly lines planned for the factory.

FIGURE 13

PLANNING SHEET FOR ASSEMBLY

PROCESS ROUTING

PROJECT NO. 3751-001 — SHEET 1 OF 8

Part Name	Sub Group	Model	Experimental Part No.	Production Part No.
TRACTOR ASSEMBLY	Assembly	80		8-8-1

Similar Part No.	Date Latest Engineering Change	Processed By	Volume	Checked By	Pieces Per Unit
		C. G.	60, 000	C.H.G.	1

Material	Size of Stock Rough	Pieces Per Bar or Sheet	Weight Per Piece	Date
Assembly				4-22-68

Oper. No.	Description of Operation	Crew Size	Operation Std. Hrs.	Setup Hours	Equipment Description	Expenditures: Expense	Expenditures: Capital
10	Load transmission, clutch housing and differential unit on stand	1	.1000	.350	Fixture Stand	$5, 000	
	(scheduled to line from storage.)				Jib Crane	2, 000	
	Remove protective covers.				Impact Wrench (2)	600	
	Assemble rear axle housing subassemblies to differential.				Bench and Hand Tools (2)	200	
					Hoists (2)	800	
					Conveyor Saddles (40)		$50
					Assembly Conveyor		$1000/ft.
20	Transfer unit to assembly conveyor. Assemble rockshaft housing	1	.1000	.350	Hoist	400	
	to transmission. Assemble rockshaft arms and covers.				Bench and Tools	100	
					Impact Wrench (2)	600	
30	Install control support assemblies.	1	.1000	.350	Impact Wrench	300	
					Bench and Tools	100	

FIGURE 14

ENGINE ASSEMBLY LINE

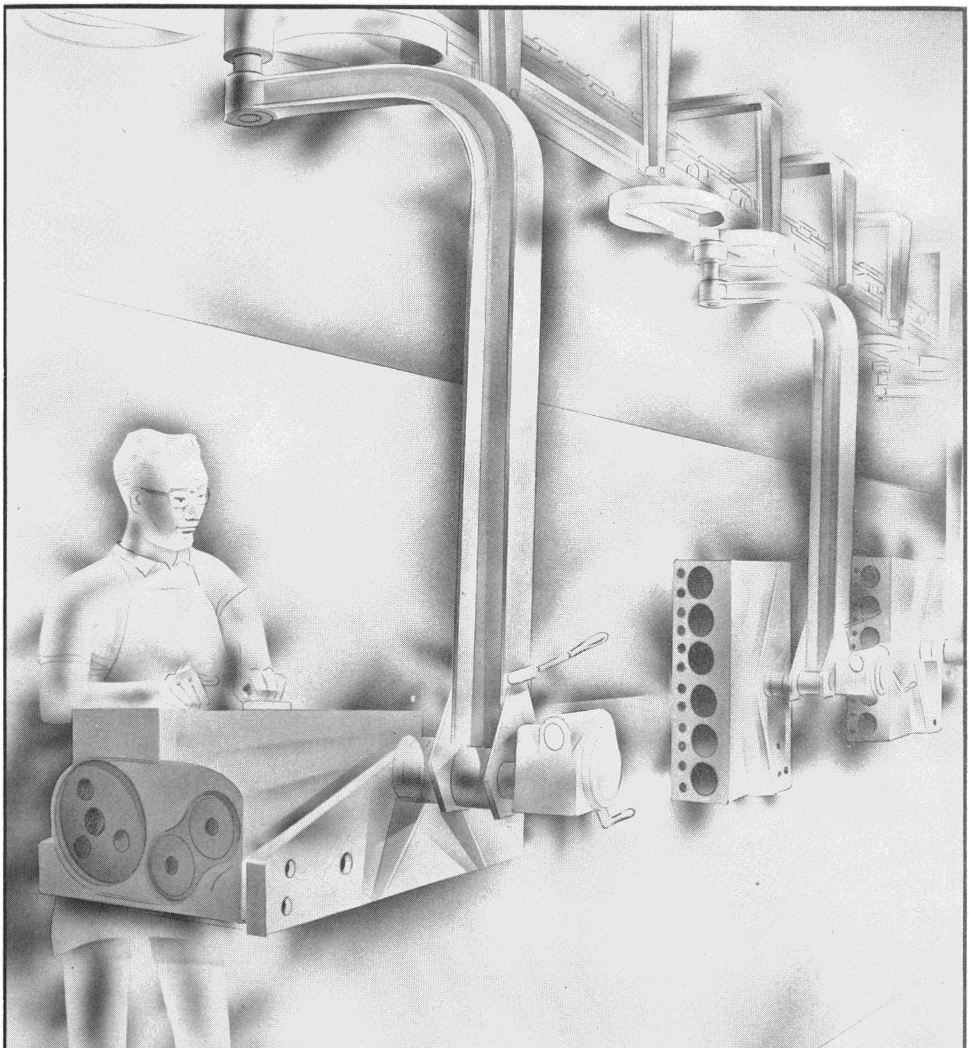
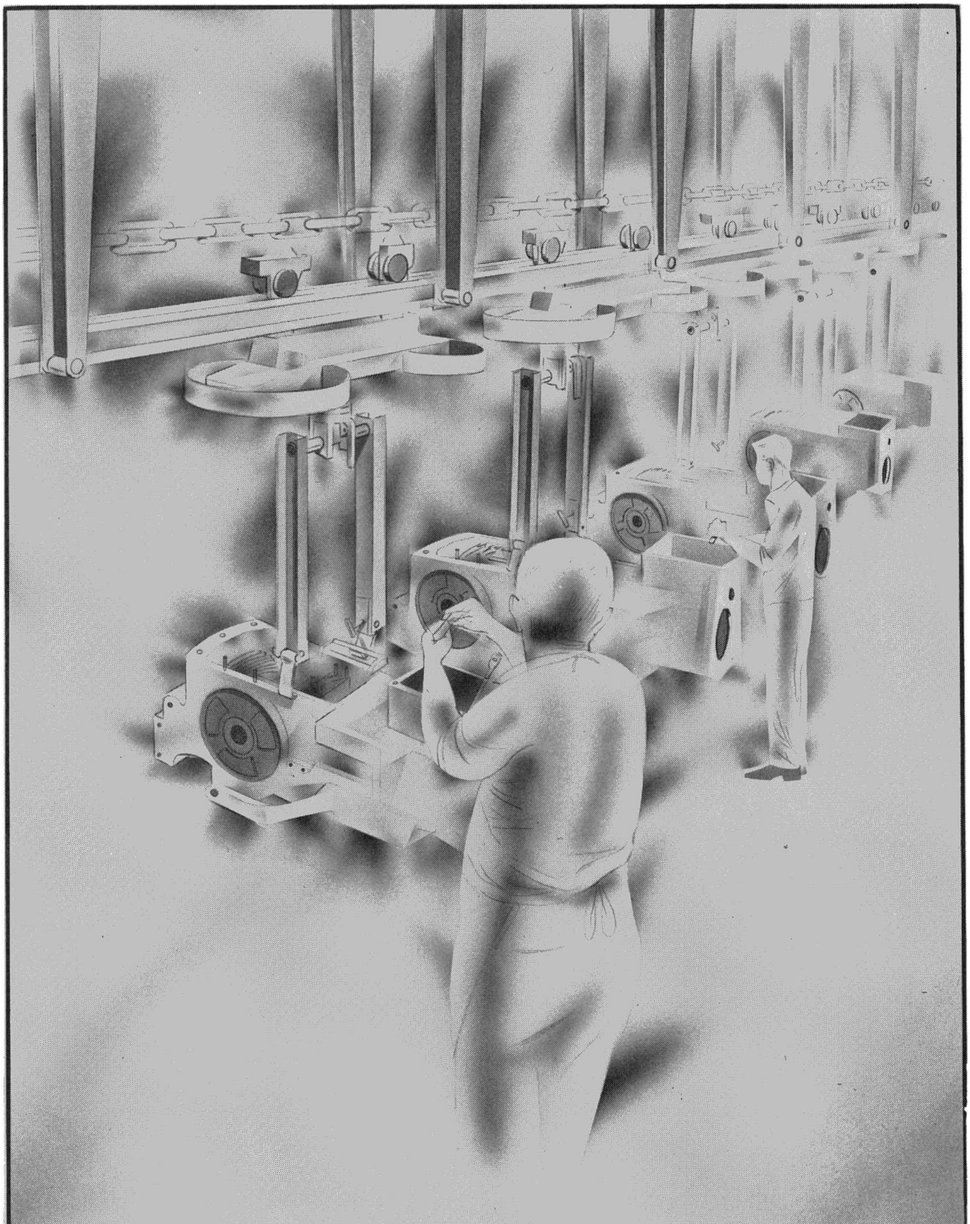


FIGURE 16

TRACTOR ASSEMBLY LINE



This examination covered all significant assembly operations. The manufacturers' parts lists were cross-checked with the operation planning sheets to ensure that all parts were included.

No significant changes in assembly techniques were specified between the production levels examined. The 20,000-unit volume level provided enough volume to justify conveyorized assembly lines, but the 90,000-unit level does not provide the volume to justify sophisticated automation of assembly operations (e.g. automatic jigs for positioning subassemblies, continuous feed of tires and other items, and subassembly lines fully scheduled to meet main assembly line requirements). These would probably be justified at a volume range of 150,000 to 175,000 units.

2. <u>EQUIPMENT REQUIREMENTS WERE DETERMINED</u>

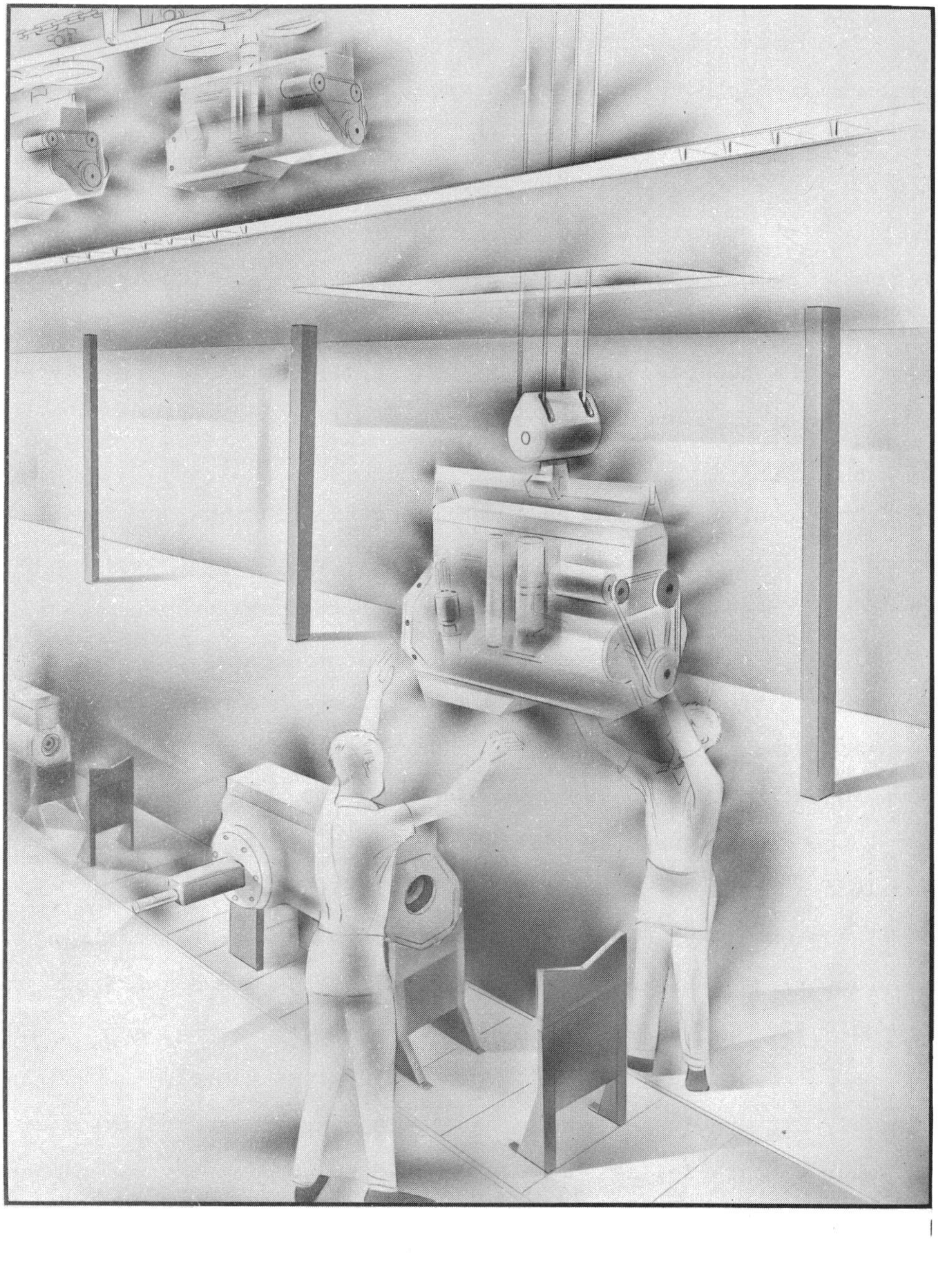
The requirements for equipment specified during the detailed operation planning were tabulated. This equipment includes such items as hoists, impact wrenches, bench fixtures, arbor presses, ovens, and paint booths.

In addition, the conveyors, stock trucks, mobile racks and special handling equipment necessary to move and store the components and subassemblies were designated. Provision was made for the additional handling and installation equipment and facilities required to permit the installation of the wide range of "hang-on" and "add and omit" options typical of tractor manufacturing. Assembly equipment requirements are summarized in Appendix 29.

For tractor assembly at the low volume level, a single assembly line would be used to handle the three sizes of tractors. A second, parallel assembly line would be used at the two higher production levels. This line would not only provide the additional capacity, but would reduce the number of setup changes.

FIGURE 15

TRANSMISSION ASSEMBLY LINE



A schematic drawing of the final assembly line for the medium horsepower model tractor appears as Appendix 30, and Figure 16 pictures the line at the "engine drop" station, where the engine is delivered to the moving tractor assembly line.

3. <u>CAPITAL REQUIREMENTS FOR ASSEMBLY OPERATIONS WERE DETERMINED</u>

The investment required to provide assembly facilities was computed in the following manner:

(1) Equipment Requirements Were Evaluated. The cost of the equipment for the assembly operations was estimated by extending the equipment lists developed earlier by current procurement costs. Appendix 29 also contains these calculations.

(2) Floor Space and Building Cost Requirements Were Projected. Floor space requirements for the assembly lines and stations were increased to include space for access aisles, storage of parts in process, and other auxiliary requirements. Construction costs were determined by extending the area required by current building cost data. These calculations are detailed in Appendix 31.

(3) Working Inventories Were Estimated. The quantities of components, subassemblies, and completed tractors that would be in process were estimated. These items were assigned values, depending upon their state of fabrication. Appendix 32 is a tabulation of inventory costs.

(4) Total Capital Requirements Were Determined. Investment capital requirements for assembly operations were calculated by totalling the investments computed previously. Table 28 summarizes capital requirements. Since the costs of assembly operations are not affected by the make-or-buy mix, no comparisons of variable and actual cost were made.

TABLE 28

TOTAL CAPITAL REQUIREMENTS FOR ASSEMBLY OPERATIONS

(Thousands of U. S. dollars)

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Machinery and equipment	$1,798	$ 3,724	$ 4,814
Building costs	1,197	2,856	3,728
Inventory	6,327	16,556	20,801
Total capital required for "permanent" facilities	$9,322	$23,136	$29,343
Additional average investment for tooling (taken as 50% of initial investment)	192	504	732
Total capital requirements	$9,514	$23,640	$30,075

4. FACILITY AND CAPITAL COSTS WERE CALCULATED

Depreciation rates of 5% on buildings and 10% on machinery were applied on a straight-line basis. Special-purpose tooling and fixtures were amortized at the rate of 33% a year to reflect obsolescence caused by styling or technological changes.

Capital costs were calculated to represent the costs of money invested in machinery, equipment, buildings, and inventories. A cost of 7.5% was used to cover interest charges on these investments. To reflect the effect of depreciation on facilities, the investment in buildings and equipment was calculated at 80% of original cost. This figure is an approximation of the investment represented by the specified facilities after from two to four years of operation. Investment in inventories was based on the calculations described earlier. Expendable supplies and hand tools were treated as having been expended at the time of purchase and were excluded from inventory.

5. LABOUR COSTS WERE DETERMINED

The manpower required by the assembly operations was determined and payroll costs projected.

(1) Assembly Man-Hour Standards Were Developed. From the operation planning sheets, labour standards were developed for the assembly operations. Table 29 summarizes the man-hour standards for the major subassemblies and for the completed tractor at the 60,000-unit volume level. The number of hours required for assembly only were considered to be 6% greater at 20,000-unit volume and 2% less at 90,000-unit volume than at the base volume of 60,000 units. These calculations are shown in detail in Appendix 33.

TABLE 29

STANDARDS FOR ASSEMBLY OPERATIONS
AT 60,000-UNIT VOLUME LEVEL

	Standard Hours per Unit		Setup Hours
Operations	Assembly	Inspection	per Occurrence
Final tractor assembly	4.100	.400	6.300
Related subassemblies	3.810	.195	8.950
Engine assembly	3.700	.300	9.350
Related subassemblies	1.250	.110	3.000
Transmission and differential assembly	2.300	.200	5.000
Related subassemblies	.645	.065	1.650
Total	15.805	1.270	

(2) The Setup Man-Hours Required Were Calculated. On the basis of the standards for setup changes specified on the operation planning sheets, the total man-hours required for these changes were calculated. Some tractor plants operate assembly lines on a random mix system, so that, within broad limits, a variety of models can be built to match order flows. Others build in sequential batches of end products. In this plant, setup costs were based on the assumption of production of tractors in sequential batches.

Setup man-hour requirements differ between output levels because two assembly lines would be used at the 60,000- and 90,000-unit levels. The use of two lines would reduce setups by allowing one line to run the medium horsepower tractor continuously. Setup changes would be required only on the second line, which would run the other two models.

(3) Manning Tables Were Prepared. The number of men required in the assembly areas was determined and manning tables prepared for each output level, as shown in Table 30. Staffing projections are based on the man-hour requirements developed earlier. They also include personnel for auxiliary operations, such as stock handling and equipment maintenance. Allowances were also made for absenteeism, training of new employees, and other operating losses on the same basis as in the stamping and machining departments. Details of all these staffing calculations appear in Appendix 33.

(4) Annual Payroll Costs Were Calculated. On the basis of wage rate and fringe benefit data provided by the Commission, the analysts calculated the total payroll costs required in the assembly areas. Detailed calculations are also to be found in Appendix 33.

TABLE 30

ASSEMBLY OPERATIONS MANNING REQUIREMENTS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Direct Labour			
Assemblers	175	494	726
Line setup men	3	3	3
Inspectors	14	40	60
Absentee and trainee replacements	17	43	64
Total direct labour	209	580	853
Indirect Labour			
Material handlers	14	41	61
Inspectors	6	16	25
Maintenance personnel	16	43	63
Total indirect labour	36	100	149
Support Staff			
Supervisory staff	17	43	63
Clerical staff	6	11	16
Total support staff	23	54	79
Total assembly manning requirements	268	734	1,081

6. ASSEMBLY OPERATING EXPENSES WERE PROJECTED

Budgets were prepared for annual purchases of such items as lubricants, coolants, and fuel for both the product and the assembly equipment; perishable tools, hand tools, and gauges; paint and finish materials; equipment replacement parts; contract repairs and calibrations; miscellaneous factory supplies; miscellaneous clerical supplies; rework and repairs; utilities; heat; and sundry expenses and contingencies.

These estimated budgets were based on the analysts' prior experience in developing budgets for assembly operations. A comparison of the budgeted amount for each level shows a range of $677,000 at the 20,000-unit level to $2,934,000 at the 90,000-unit level. Detailed budgets are to be found in Appendix 34.

7. TOTAL ASSEMBLY COSTS WERE COMPILED

All of the cost factors examined previously were tabulated to determine annual totals for the selected volumes. These costs factors are displayed in the pro forma statement of operation costs in Appendix 35. Unit costs were determined by dividing annual totals by unit volume. Table 31 presents the results of this summary analysis.

TABLE 31

SUMMARY OF ASSEMBLY COSTS PER UNIT

(U. S. dollars)

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs			
Labour	$ 90	$ 82	$ 80
Operating expenses	45	41	41
Variable costs	$135	$123	$121
Fixed Costs			
Facility costs	$ 25	$ 20	$ 17
Capital costs	33	28	24
Fixed costs	$ 58	$ 48	$ 41
Total unit cost	$193	$171	$162
Memo:			
Add allocated support costs (Table 39)	70	56	47
Total cost, including support costs	$263	$227	$209

Only minor reductions in variable costs result from increased assembly volume. The significant changes in unit cost result from increased utilization of assembly facilities and from reduction in capital costs per unit, i.e. that higher capacity facilities cost less per unit of capacity.

VIII

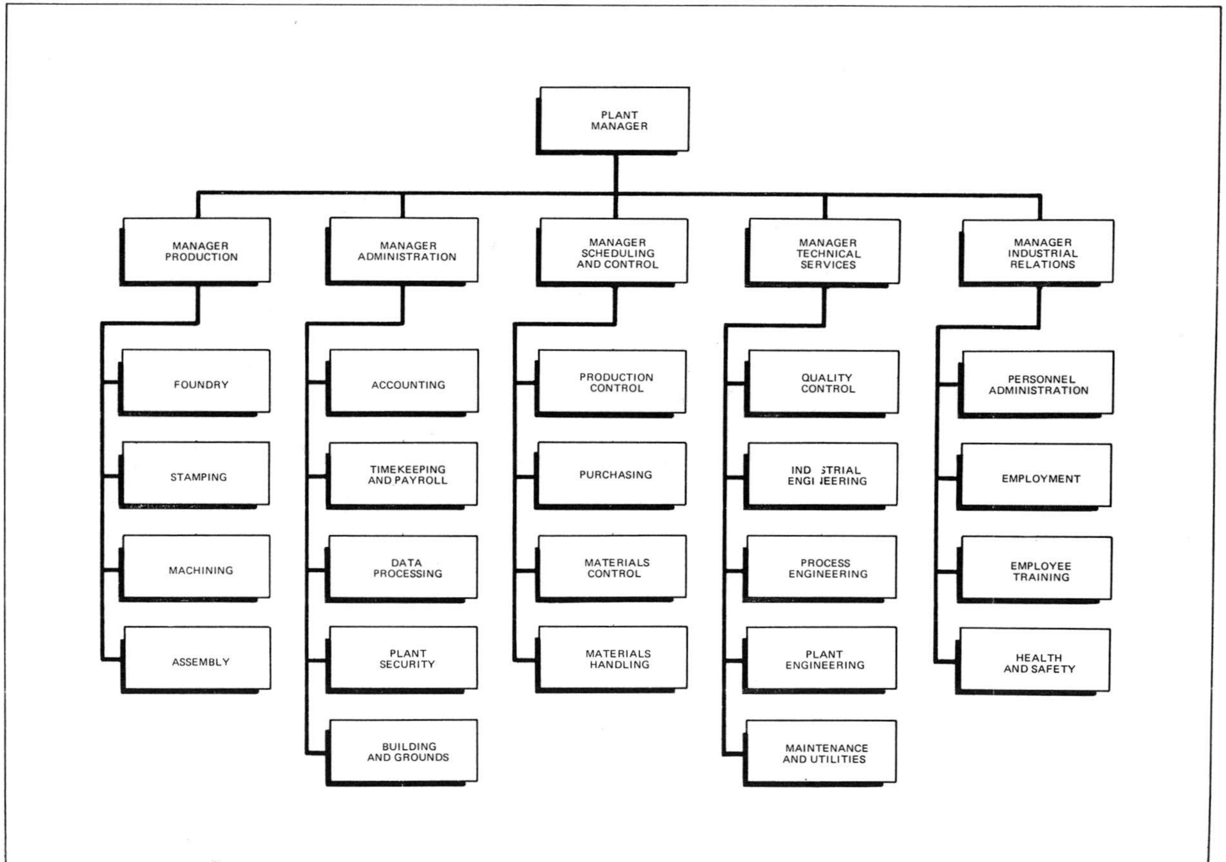
EXAMINATION OF ADMINISTRATIVE AND SUPPORT COSTS

The operation of manufacturing plants requires performance of certain functions in support of the production activity. To complete the study of costs in tractor manufacture, it was necessary to identify and evaluate these support functions for each output level. As a manufacturing organization increases in size and complexity, specialist supporting groups evolve to perform such functions as accounting, production planning and control, material procurement, and clerical operations as well as maintenance and janitorial services. The cost of manning and equipping these groups represents between 8% and 9% of total tractor costs within the volume range studied. These costs are not directly related to particular productive operations and, therefore, are labelled as administrative and support costs. Those supports directly associated with or physically located in particular plants were dealt with in the chapters describing the plant operations. The common administrative and support costs are examined in the paragraphs that follow.

The examination of administrative and support functions is quite similar to the analysis of productive functions, in that the same techniques are applied to define the necessary facilities and to determine the staffing requirements. However, because of the basic nature of these clerical and technical functions, staffing usually determines facility requirements rather than vice versa. Floor space and equipment needs are determined by the number of personnel required to perform the service, whereas in the case of

FIGURE 17

TRACTOR FACTORY ORGANIZATION CHART



most production operations the number of machines required dictates the number of operators. For this reason, the usual analytical sequence was to define the function, determine the required staff, and then project facility requirements.

1. THE ADMINISTRATIVE AND SUPPORT FUNCTIONS WERE IDENTIFIED AND AN ORGANIZATION CHART WAS DEVELOPED

The administrative and support functions required for an efficient operation were identified. The functions included were those required to support product manufacture and not those related to sales and distribution or general corporate management. This identification was based on the analysts' experience and on a review of current manufacturing management publications.

Having defined the required functions, the analysts developed an appropriate organization structure, as depicted in Figure 17. This chart presents a theoretical structure of authority and responsibility relationships and shows how the production departments, discussed earlier, fit into the rest of the organization. This organization places related departments under the same managers and limits the number of subordinates reporting to a single manager. With competent staffing, this structure would provide the high level of managerial efficiency assumed throughout the study. It must be recognized, however, that while the functions shown on the chart will be carried out at all production levels, they will be given different degrees of attention at the different volume levels. Numbers of staff will increase with higher volumes, and the greater specialization will allow more concentration on particular tasks, thereby improving costs, given equal managerial skills.

It should also be emphasized that the chart assumes a company with one plant making tractors only. To the extent that it were a multi-plant, multi-product company, or if it were part of a multinational corporation some of these functions would be performed in whole or in part by headquarters staff. There would, presumably, be some saving in administrative and support costs as a result.

For the purpose of further analysis, the support functions were grouped as follows:

-- *Office support and administration:* accounting, timekeeping and payroll, data processing, production control, purchasing, and materials control.

-- *Materials handling:* receiving, in-process movement and storage, and shipping.

-- *Factory support:* plant security, building and grounds, maintenance and utilities, quality control, industrial engineering, process engineering, plant engineering, personnel administration, employment, employee training, and health and safety.

To show these service functions in the perspective in which they will be discussed, this grouping crosses lines of authority depicted in the organization chart.

2. OFFICE SUPPORT AND ADMINISTRATIVE COSTS WERE ESTIMATED

The departments included in office support and administration were listed in the previous section. The definition of each department's activities is as follows:

Accounting: the collection, recording, and reporting of cost data; including handling of accounts payable and disbursements as well as allocation of operating costs; not including sales, accounts receivable, profit and loss, and corporate level general accounting.

Timekeeping and payroll: the reporting of hours worked, calculations of earnings and payroll deductions, preparation of paychecks, and related recordkeeping.

Data processing: the mechanized and computerized manipulation of information required by accounting, payroll, production control, and other numerically based functions, including the input of reported data, manipulation, and output reporting and programming of the data processing equipment.

Production control: advance planning, operation scheduling, output reporting, and follow-up.

Purchasing: the location of vendor sources, comparison of prices or bids, and procurement of materials and components.

Materials control: the clerical and expediting functions involved with co-ordinating the physical movement of materials.

(1) Office Support and Administrative Staffing Was Determined. The number of managerial, supervisory, technical, and clerical employees required by the office-based support departments was determined for each production level. The number of general management personnel and supporting clerical staff was also projected. These staffing projections were based on the analysts' experience in determining organization requirements for these functions. They are not based on the actual staffing of any one firm, but rather on a composite of several. The office support staffing figures assume the use of such modern management techniques as:

-- The use of computers, not only to process volumes of data, but also to make routine management decisions, such as the generation of purchase orders, material releases, and machine change schedules.

-- The use of process control procedures that specify critical operating conditions and provide for follow-up inspections to ensure that actual conditions correspond to those specified. These techniques control product quality "at the source" and avoid reliance on expensive, 100% inspection.

-- The use of network planning techniques (PERT, CPM, etc.) to control complex projects such as facilities modifications or major retooling.

-- The use of standard data for individual work elements and machining operations to synthesize time standards without making repetitive observations.

Table 32 summarizes the staffing requirements for the office support and administrative departments in a manning table. Appendix 36 lists these staffing requirements in detail and also includes the resulting payroll costs.

TABLE 32

OFFICE SUPPORT AND ADMINISTRATIVE MANNING REQUIREMENTS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Managers	6	8	8
Superintendents	5	9	14
Supervisory and technical staff	43	85	122
Clerical staff and hourly workers	107	246	331
Total office support and administrative manning requirements	161	348	475

(2) Capital Requirements for Office Support and Administrative Facilities Were Projected. The office space and equipment requirements for the support and administrative staff were projected. These space requirements include offices plus auxiliary space for aisles, lobbies, file rooms, and conference rooms. These floor space projections were based on per-person standards of 50 square feet for clerical employees; 100 square feet for supervisory and technical employees, and 250 square feet for superintendents and managers. Additional allowances were made to cover the auxiliary areas.

Capital requirements for equipment such as typewriters, calculators, and file cabinets were estimated at the rate of $500 per clerical employee. Construction and furnishings costs were computed by extending floor space requirements by $30 per square foot. This figure, at current prices, covers all building costs and such furnishings as draperies, carpets, desks, tables, and chairs. Table 33 summarizes the capital requirements for facilities for these support functions. Detailed calculations of equipment costs are presented in Appendix 37. Construction cost calculations are shown in Appendix 38.

TABLE 33

TOTAL CAPITAL REQUIREMENTS FOR OFFICE SUPPORT AND ADMINISTRATIVE FUNCTIONS

(Thousands of U. S. dollars)

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Machinery and equipment costs	$ 74	$ 163	$ 216
Building costs	492	1,002	1,368
Total	$566	$1,165	$1,584

3. PLANT MATERIALS HANDLING COSTS WERE EXAMINED

The receiving, storing, moving, and shipping of raw materials, components, and finished products require a substantial expenditure for staff and facilities. The objective of this function is to provide the needed material at the right place, on time, and at minimum cost. The basic requirements for optimizing handling costs are complete and precise knowledge of the material being moved and the appropriate use of labour-saving mechanized equipment. The systems selected incorporate the latest proven developments in materials handling, such as automatic moving equipment, "high cube" storage system (explained below), automatic retrieval systems, unitized loads, and common size containers and carriers.

These systems, coupled with comprehensive, computer-based production and movement control procedures, would minimize both handling costs and losses caused by shortages.

(1) The Volumes of Materials To Be Moved and Stored Were Determined. The items to be handled were identified as to size and movement pattern through a review of the parts lists and operating planning sheets. Both purchased and fabricated components were classified with regard to the number of loads to be moved per tractor. Loads were defined as toteboxes, pallets, or metal parts tubs, as appropriate.

The analysts estimated the number of loads required for each item per 100 tractors. The patterns of movement were also determined. Load requirements were grouped by movement pattern to determine how many loads would be moved between particular departments. The summary of material movement and storage data is shown in Appendix 39.

(2) Movement Distances Were Determined. The schematic plant layouts shown in Figures 18, 19, and 20 were developed. These layouts show the sizes and logical proximity relationships of the major production departments and the component storage warehouse. The layouts were drawn to scale and used to determine the distances involved in moving materials and components through the plant. They were not intended, however, to indicate a final site plan for the operation.

(3) Equipment for Materials Movement Was Selected. A towline was selected for the long-distance moves between departments. This device is essentially a powered chain running in a recessed channel in the plant floor and provides automatic movement of stock as the chain tows wheeled carts along a fixed route. Switching equipment built into the carts makes it possible to shunt them off at selected sidings along the main route. The movement of a cart from one point to another requires only setting its switching device and pushing it onto the towing line. The

FIGURE 18

SCHEMATIC PLANT LAYOUT FOR 20,000 VOLUME LEVEL

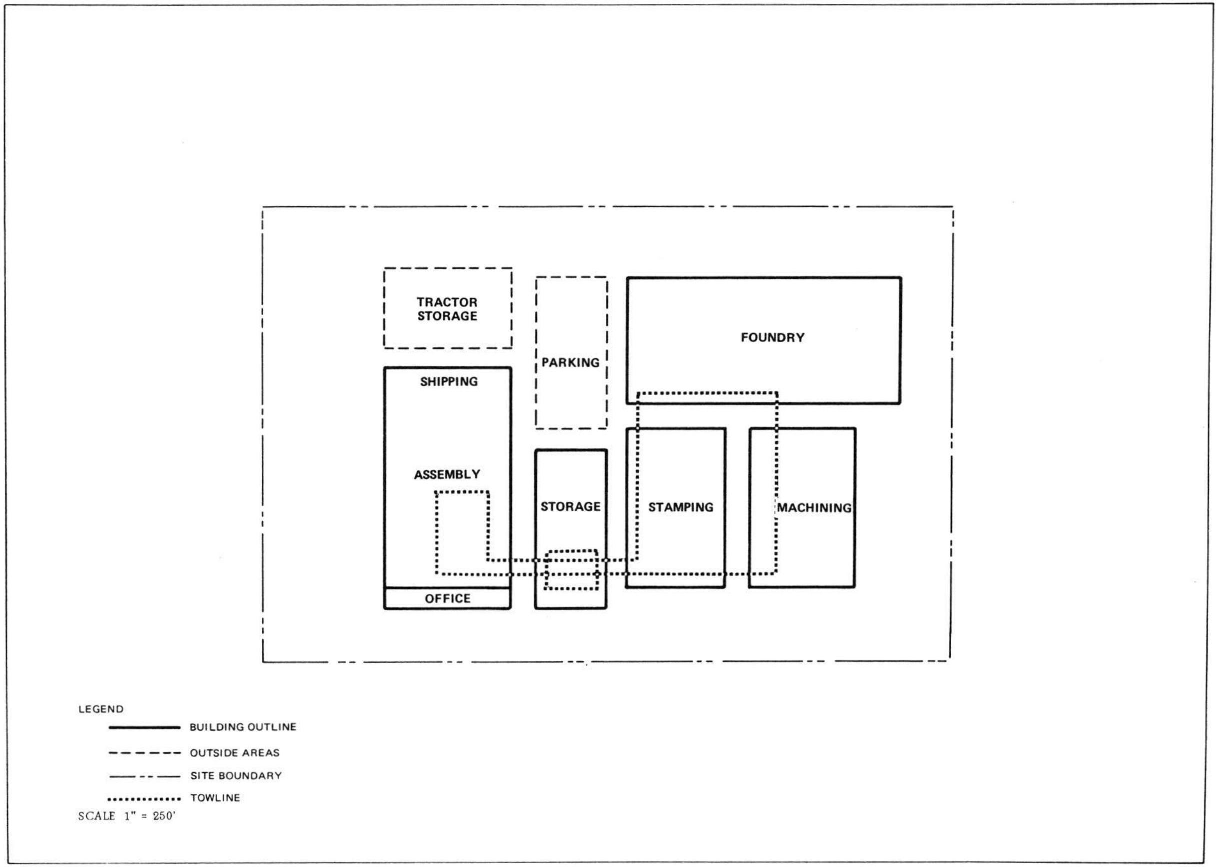


FIGURE 19

SCHEMATIC PLANT LAYOUT FOR 60,000 VOLUME LEVEL

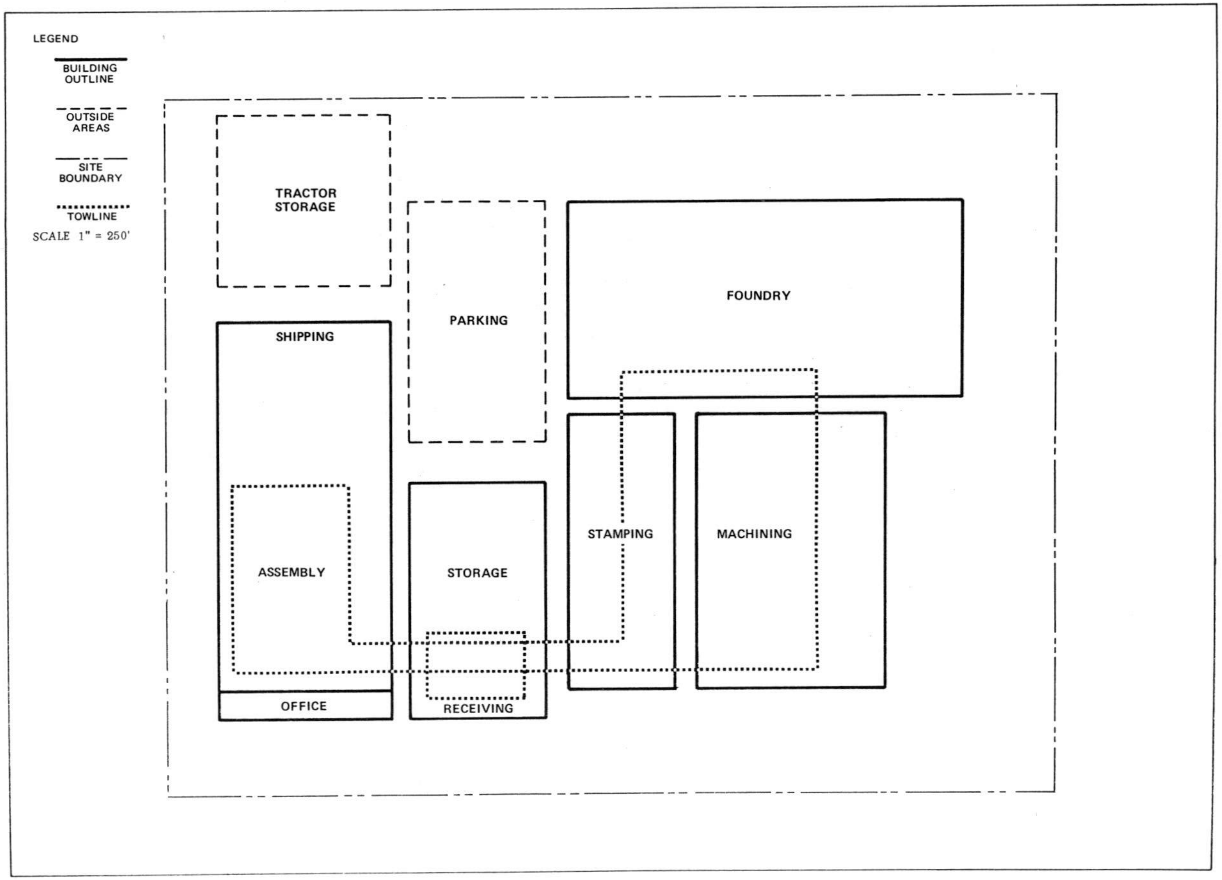
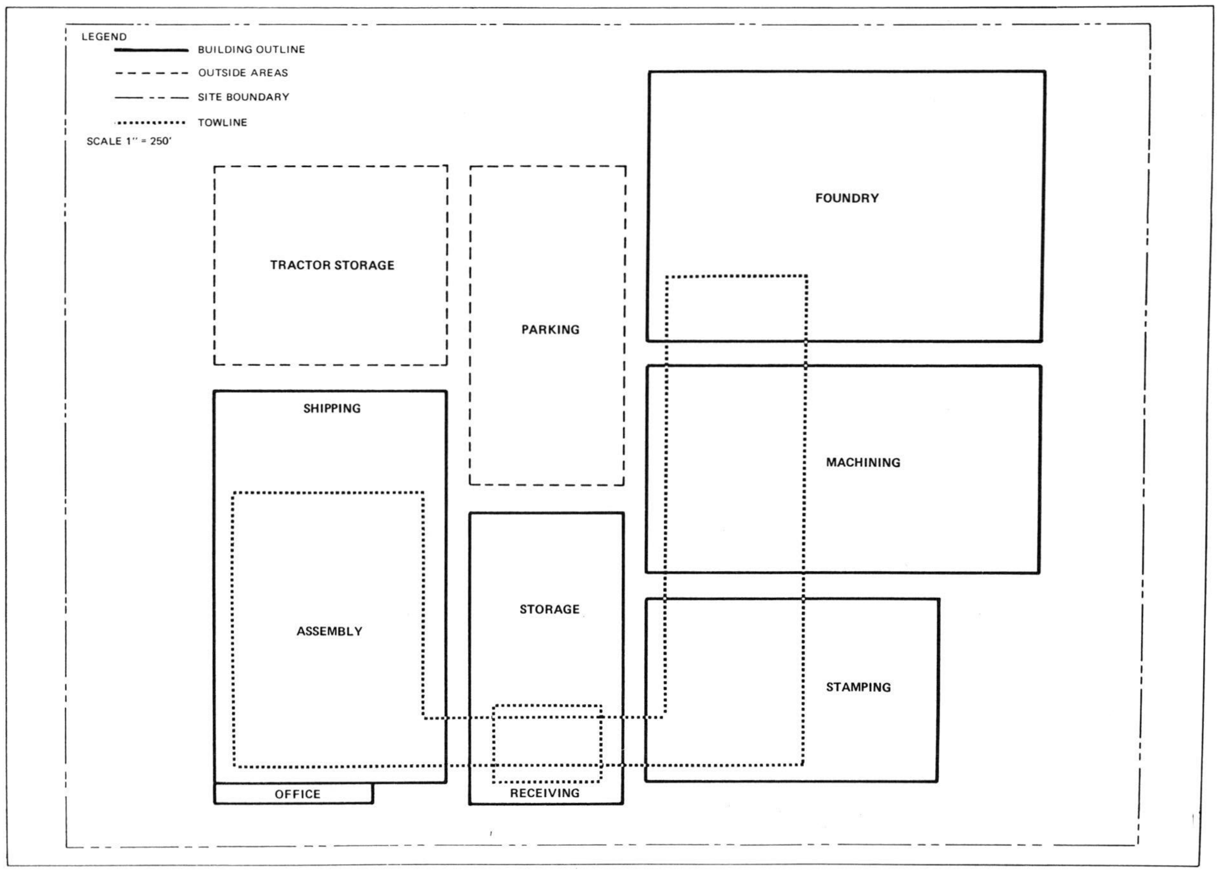


FIGURE 20

SCHEMATIC PLANT LAYOUT FOR 90,000 VOLUME LEVEL



principal advantage of the towline is that it provides constant movement service with a minimum labour cost.

Movement from the towline to the point of use or storage would be accomplished primarily by fork trucks. The number of trucks required in the warehouse and receiving areas was calculated with the use of standard time data and the projected movement volume.

(4) Requirements for Materials Facilities Were Determined. Warehouse floor space and storage equipment requirements were determined for the storage of components. These calculations were based on a "flexible location" system of storage -- that is, particular items would not be assigned permanent locations in the warehouse, but would be placed in whatever racks or floor space was available at the time of receipt. In situations requiring storage of a large number of different items, this system conserves space since it is necessary to provide only for the average, rather than the maximum, inventory of each item.

A common storage building was planned for all components, whether purchased or fabricated. Heavy castings and raw steel stock would be stored on the floor of a special area of this warehouse. Warehouse facility requirements were calculated on the basis of an average inventory of all the materials and components to be stored including a 20% allowance to cover surges in incoming volume.

An automated storage system, which uses computer-directed robot cranes, was selected for the storage and retrieval of most components. This high cube system provides substantial savings, both in labour and floor space requirements, over the cost of using fork trucks. The words "high cube" indicate cubic storage products, piled much higher than in other storage systems. The cranes would automatically put away and retrieve loads from racks 40 feet high, as opposed to those 20 feet high in a manned truck system. Access aisles would require approximately five feet rather than the ten feet or more needed for fork trucks. In addition to the economic advantages explored in Appendix 40, the automated storage system provides more precise control. The computer would keep location records that are free of errors -- a condition very difficult to achieve with flexible locations and a large number of truck operators.

(5) The Investment in Materials Handling Facilities Was Projected. The required investment in materials handling equipment, warehouse floor space, and storage racks was calculated by extending the facilities requirements by current purchase or construction costs. These requirements are summarized in Table 34 and supporting calculations are to be found in Appendices 41 and 42.

TABLE 34

TOTAL CAPITAL REQUIREMENTS FOR MATERIAL HANDLING AND STORAGE FUNCTIONS

(Thousands of U. S. dollars)

	20, 000 Units per Year	60, 000 Units per Year	90, 000 Units per Year
Machinery and equipment costs	$3, 050	$ 8, 448	$12, 320
Building costs	1, 028	2, 760	4, 220
Total	$4, 078	$11, 208	$16, 540

(6) Materials Handling Staffing Requirements and Payroll Costs Were Projected. The warehousemen, equipment operators, expeditors, and clerks required by the materials handling system

were identified. These projections were based on an examination of the fixed complement necessary to perform each function, plus the additional staff required by the volume of materials handled. Fixed staff requirements were estimated from a review of the operations performed and the configuration of the plant areas involved. Variable staffing was determined through the use of standard time data. Allowances were made to provide for absenteeism, training of new employees, and other operating losses. These allowances were made on the same basis as that used for the assembly areas. The manpower projections for the materials handling function are shown in the materials handling manning table, Table 35, and detailed calculations appear in Appendix 43.

TABLE 35

MATERIAL HANDLING MANNING REQUIREMENTS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Superintendents	-	1	1
Supervisory and technical staff	5	13	21
Clerical staff	3	7	11
Hourly workers	62	158	223
Total material handling manning requirements	70	179	256

Total annual costs for wages and fringe benefits were calculated in the same manner as that used during the examinations of the fabrication functions. Appendix 43 also contains details of the payroll cost computations.

4. COSTS OF OTHER FACTORY SUPPORT FUNCTIONS WERE PROJECTED

In addition to materials handling, a number of other factory-based support functions are required. These functions include technical, clerical, and trade disciplines which are related to the total operation of the plant, and their costs were not included in the examinations of individual processes. The definition of each function is listed below:

Plant security: the guarding and patrolling of the plant and grounds to prevent damage from fire, theft, and vandalism, with personnel including gate guards, watchmen, receptionists, and firemen.

Building and grounds: the janitorial services required to maintain orderly and attractive facilities.

Maintenance and utilities: the maintenance services required for the plant as a whole as opposed to those provided by the specialized repairman assigned to each production department, including services of electricians, plumbers, carpenters, millwrights, instrument repairmen, boiler firemen, and labourers.

Quality control: the specification and policing of quality standards for components and completed products; including identification of procedures, machine settings, and operating conditions that affect critical quality characteristics; also including spot checks of these factors in the operating departments as well as sample reinspections to audit performance of floor inspectors.

Industrial engineering: the development of methods and procedures, setting of time standards, and analysis of cost reduction opportunities, including the performance of make-or-buy investigations.

Process engineering: the planning of manufacturing operations, including specification of machinery, speeds and feeds, tooling designs, and movement rates.

Plant engineering: the development of plant and facility modification specifications, supervision of construction and modification projects, and preparation of preventive maintenance procedures.

Personnel administration: the handling of employee records, insurance, and personal matters.

Employment: The recruiting, screening, and hiring of both salaried and hourly paid employees.

Employee training: the orientation of new employees, development and supervision of skills training programs, and proficiency testing and certification, including training of supervisors and on-the-job instructors.

Health and safety: the programs designed to safeguard the employees' physical well-being, including industrial nursing and first aid, inspections to detect hazardous conditions, and provision of personal safety and recreation equipment.

Further, outside organizations would be used to provide services that are not in the main line of company business. Examples of these include food catering in the plant lunchroom and handling of trash other than scrap that is re-used in the plant.

(1) Factory Support Staffing and Payroll Costs Were Developed. The number of supervisory skilled, semiskilled, and unskilled employees required to perform the factory support functions was determined. These projections were based on metalworking trade publication data, with regard to the relationship between the number of men assigned to these functions and the number assigned to production activities. These data were based on a survey of more than 83 plants performing similar metal fabrication operations. Adjustments were made to incorporate the analysts' experience and judgment. The project staffing requirements for the factory support functions are summarized in Table 36.

TABLE 36

FACTORY SUPPORT MANNING REQUIREMENTS

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Managers and superintendents	9	17	20
Supervisory and technical staff	59	137	193
Clerical staff and hourly workers	194	550	743
Total factory support manning requirements	262	704	956

Total annual costs for wages and fringe benefits were calculated in the same manner as that used during the examination of the fabrication functions. Details of the staffing requirements and payroll cost calculations can be found in Appendix 44.

(2) Capital Requirements for Factory Support Facilities Were Determined. The investment in floor space, equipment, and other facilities for the factory support functions was estimated. The facilities included offices, maintenance shops and equipment, security fencing and guardhouses, groundkeeping and snow-removal equipment, and parking-lot paving and lighting. The costs of special equipment for particular support activities were also estimated. Examples of such equipment include blueprint reproduction machines for engineering functions, motion picture and slide projectors for employee training, and testing equipment for quality control. The examination also accounted for the acquisition and preparation of the site for the entire plant.

The projections were based on the results of the following studies:

-- A review of the needs of the technical staff.

-- A review of the number of maintenance and janitorial employees and the functions they would perform.

-- Estimations of the janitorial, groundkeeping and snow-removal equipment needed, based on the number of employees required by these functions and on the physical areas involved.

-- Calculation of parking facility requirements based on total number of employees and extended by current costs for paving and lighting.

-- Computation of the acreage required for an adequate plant site and estimation of cost of purchase and landscaping.

-- Estimations of other costs and miscellaneous items.

The facility investments required for the factory support functions are summarized in Table 37 and detailed calculations appear in Appendices 45 and 46.

TABLE 37

TOTAL CAPITAL REQUIREMENTS FOR FACTORY SUPPORT FUNCTIONS

(Thousands of U. S. dollars)

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Machinery and equipment costs	$ 597	$1,809	$2,442
Building costs	630	1,785	2,520
Site preparation costs	350	675	975
Total	$1,577	$4,269	$5,937

5. SUPPORT, FACILITY, AND CAPITAL COSTS WERE PROJECTED

Costs of depreciation, taxes, insurance, and interest on all support facilities were calculated in the same manner as that used for the component fabrication functions.

6. BUDGETS FOR SUPPORT FACILITIES WERE ESTABLISHED

Budgets were prepared for the annual cost of such items as equipment rental; lubricants and fuel for equipment; perishable tools, equipment parts, and maintenance equipment repairs; maintenance materials; operating aids and shipping supplies; janitorial and groundkeeping supplies; utilities and heat for support areas, and sundry expenses and contingencies.

These budgets were based on estimates prepared by several analysts who are familiar with the particular functions examined. Because of the nature of these expenses and the depth of the analysis performed, these estimates necessarily are subject to a higher margin of error than most of the other cost factors examined. However, the impact on total unit cost of even a 20% error in this area would be insignificant. These annual expenses are listed in Appendix 47.

7. TOTAL COSTS OF FACTORY SUPPORT FUNCTIONS WERE COMPILED

All of the cost factors examined above were tabulated to determine annual totals for the selected volumes. These cost factors are displayed in the pro forma statement of operating costs in Appendix 48 and are summarized in Table 38. As mentioned earlier, those costs do not include plant foremen, clerical staff in plants, and other support costs which are directly associated with and charged to individual plants.

TABLE 38

SUMMARY OF TOTAL ADMINISTRATIVE AND SUPPORT COSTS PER UNIT

(U. S. dollars)

	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Variable Costs			
Salaries and fringe costs	$204	$162	$148
Support expenses	75	69	67
Variable costs	$279	$231	$215
Fixed Costs			
Facility costs	$ 39	$ 35	$ 34
Capital costs	18	17	16
Fixed costs	$ 57	$ 52	$ 50
Total unit cost	$336	$283	$265

Table 39 prorates the administrative and support costs established in Appendix 48 and Table 38 across the four process functions or "plants" identified in the study. These allocated

TABLE 39

ALLOCATION OF ADMINISTRATIVE AND SUPPORT COSTS

AMONG DIFFERENT PLANT OPERATIONS

(U.S. dollars)

A. The Total Allocation by Operation

Plant Operation	Plant Size		
	20,000 Units	60,000 Units	90,000 Units
Foundry	$ 99	$ 81	$ 73
Stamping plant	35	23	26
Machining operations	132	123	119
Assembly operations	70	56	47
Total	$336	$283	$265

B. The Basis of the Allocation

The Administrative and Support Costs to be Allocated (Table 38)

	20,000 Units	60,000 Units	90,000 Units
Variable	$279	$231	$215
Fixed	57	52	50
Total	$336	$283	$265

Percentages for Allocation of Variable Administrative and Support Costs, Based on the Proportion of Labour Cost in Each Plant or Operation

	20,000 Units	60,000 Units	90,000 Units
Foundry	26.6	26.0	25.2
Stamping plant	10.9	8.6	10.8
Machining operations	39.9	44.2	44.7
Assembly operations	22.6	21.2	19.3
Total	100.0	100.0	100.0

Percentages for Allocation of Fixed Administrative and Support Costs, Based on the Proportion of Facilities and Capital Costs in Each Plant or Operation

	20,000 Units	60,000 Units	90,000 Units
Foundry	44.4	40.6	37.2
Stamping plant	8.8	6.5	6.6
Machining operations	35.4	40.4	45.8
Assembly operations	11.4	12.5	10.4
Total	100.0	100.0	100.0

support costs have been shown as a cost item in each plant's summary cost table. While the purpose of this allocation is to be able to identify to some extent the complete cost of operating any one of these plants separately, it must be acknowledged that the result is an understatement of individual plant costs. By "building" the four plants at one location, the shared administrative and support costs will be significantly lower than if they were separated by geography or by being in different organizations.

At the same time, the exercise is useful in establishing a basis for the total costs of each type of plant operation. Each plant is given an appropriate share of the joint administrative and support burden.

IX

EXAMINATION OF TOTAL UNIT COSTS

In the final step of the manufacturing cost study, all cost elements were combined into projected total unit costs. A major portion of manufacturing costs cannot be assigned directly to particular models or units of production. Such items as managerial salaries, plant depreciation, support services, and capital costs must be allocated on an arbitrary basis. The allocation of such "overhead" items has been the subject of much study and debate by cost accountants and managerial analysts. Several bases, such as direct labour hours or dollars, material weight or cost, machine hours required, or floor space occupied, are used for their proration. Satisfaction of the basic study objective required only that costs be allocated consistently at each of the volume levels examined. Therefore, total unit costs were computed first on the basis of a simple allocation of overhead costs.

Examination of unit costs for different models, however, requires a more sophisticated treatment of overhead costs. During the comparison of model costs described later in the chapter, these items were allocated on the basis most appropriate to the particular process under consideration.

To explore the effect of temporary fluctuations in output, each cost element was examined at 20% above and below the planned volume levels. This examination identifies the effect of such items as supplementary unemployment benefits and overtime premiums on total costs during slack and peak periods.

1. SIGNIFICANT ECONOMIES OF SCALE EXIST IN TRACTOR MANUFACTURE

Examination of total unit costs indicates that substantial cost economies can be realized by increasing production within the range examined.

(1) Per-Unit Costs Decrease $754 between the 20,000- and 90,000-Unit Volume Levels. The cost data developed during the earlier phases of the study were consolidated into the unit cost comparison shown in Table 40. This table summarizes the costs of the major processes and the support functions.

As noted earlier, the 20,000-unit volume production cost for the actual make-buy mix is $51 higher than for the same cost for the constant make-buy mix. This apparent anomaly is explained in Chapter VI, Section 8, by the decision to purchase a number of "borderline" engine components involving certain risks at slightly higher costs rather than fabricate them, because they would require a substantial expenditure for facilities and start-up costs. Since the decision criterion used for make-or-buy decisions on individual components was 20%, these parts were considered purchased items.

Increased fabrication of components at the 90,000-unit level reduced the purchase of parts subject to make-buy decision to $41 at the actual make-buy mix against $396 at the constant make-buy mix. This $355 cost reduction is only partly offset by manufacturing cost increases of $201, for a net cost reduction to the manufacturer of $154.

(2) Reduced Materials Costs Constitute the Largest Savings in Manufacturing Costs. Table 41 summarizes the total unit cost differences both by the variable and fixed elements of cost (materials, labour, etc.) and by the two causes which operate on each element at the three volumes. The purchased parts costs are expressed in terms of the medium horsepower tractor costs, set out

TABLE 40

SUMMARY OF PER UNIT PRODUCTION COSTS

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Purchased Parts Costs						
Not subject to make-buy decision	$1,519	$1,420	$1,377	$1,519	$1,420	$1,377
Subject to make-buy decision	437	408	396	604	408	41
Total purchased parts costs	$1,956	$1,828	$1,773	$2,123	$1,828	$1,418
Manufacturing Costs						
Foundry	$ 581	$ 490	$ 469	$ 564	$ 490	$ 488
Stamping plant	177	138	128	175	138	187
Machine shop	581	502	478	484	502	601
Assembly plant	193	171	162	193	171	162
Total manufacturing costs	$1,532	$1,301	$1,237	$1,416	$1,301	$1,438
Administrative and support costs	$ 336	$ 283	$ 265	$ 336	$ 283	$ 265
Total costs	$3,824	$3,412	$3,275	$3,875	$3,412	$3,121

Source: Tables 6, 17, 23, 27, 31, 38.

TABLE 41

UNIT COST DIFFERENCES BETWEEN VOLUMES
(U.S. dollars)

	Cost Decrease (Increase) from 20,000- to 60,000-Unit Volume Due to			Cost Decrease (Increase) from 60,000- to 90,000-Unit Volume Due to			Cost Decrease (Increase) from 20,000- to 90,000-Unit Volume Due to		
	Increased Components Fabricated	Volume Increase	Combined Effect, Both Factors	Volume Increase	Increased Components Fabricated	Combined Effect, Both Factors	Volume Increase	Increased Components Fabricated	Combined Effect, Both Factors
Variable Costs									
Material									
Parts not subject to make-buy decision[1/]	-	$ 99	$ 99	$ 43	-	$ 43	$142	-	$142
Parts subject to make-buy decision[1/]	$167	29	196	12	$355	367	41	$522	563
Production plant materials[2/]	(50)	15	(35)	6	(91)	(85)	21	(141)	(120)
Material costs	$117	$143	$260	$ 61	$264	$325	$204	$381	$585
Labour	(34)	47	13	21	(52)	31	68	(86)	(18)
Operating expenses	(8)	18	10	2	(14)	(12)	20	(22)	(2)
Support costs	-	48	48	16	-	16	64	-	64
Total variable costs[2/]	$ 75	$256	$331	$100	$198	$298	$356	$273	$629
Fixed Costs									
Facility costs	$(18)	$120	$102	$ 25	$(29)	$ (4)	$145	$(47)	$ 98
Capital costs	(6)	36	30	12	(15)	(3)	48	(21)	27
Total fixed costs[2/]	$(24)	$156	$132	$ 37	$(44)	$ (7)	$193	$(68)	$125
Approximation of total unit cost differences	$ 51	$412	$463	$137	$154	$291	$549	$205	$754

1/ Medium-horsepower tractor.
2/ Average tractor.
Source: Table A49-1.

in detail in Appendix 2; manufacturing costs are taken from the average tractor costs set out in each process chapter. Together they form a reasonable proxy for total costs.

The first of these causes operating to reduce costs is volume alone, the difference in costs when the same components are made and bought at different volumes. The second is the effect of the changing make-buy decisions that are economically justified at the different volumes. Table 41 is founded on Appendix 49.

The largest cost change between the 20,000- and 90,000-unit volume levels is the $585 reduction in materials costs, made up of $204 resulting from the savings from economies of quantity purchasing and $381 as the result of the increase in number of components fabricated instead of purchased. This last number, $381, is itself a combination of a $522 reduction in the value of outside purchased parts and an increase of $141 in the materials needed to make these parts in the foundry, stamping plant, and machine shop. The $381 cost decrease is further offset by increases in labour and operating expenses and in fixed costs, and the resulting $205 decline can be finally attributed to the decision to make items instead of buy them.

Table 41 further reveals that it will cost $754 per tractor less to produce at the 90,000-unit volume than at the 20,000-unit volume, and that production at the 60,000-unit volume will be $463 less costly than at the 20,000-unit volume, but $291 more expensive than at the 90,000-unit volume.

(3) Some Savings in Labour and Related Operating Expenses Result from Better Utilization of Setup and Fixed Complement Staff. Based on the constant make-buy comparison, savings of about $88 in labour and operating expenses would be realized between the lowest and highest levels. These savings result primarily from the fact that fewer setup and indirect labour-hours

TABLE 42

TOTAL STAFFING REQUIREMENTS

	Actual Make-Buy Mix		
	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Foundry			
Direct labour	201	608	962
Indirect labour	92	222	344
Support staff	28	66	99
Total foundry staff	321	896	1,405
Stamping Plant			
Direct labour	96	236	478
Indirect labour	18	38	69
Support staff	13	27	46
Total stamping plant staff	127	301	593
Machining Operations			
Direct labour	386	1,253	2,042
Indirect labour	48	139	250
Support staff	25	64	120
Total machining operations staff	459	1,456	2,412
Assembly Operations			
Direct labour	209	580	853
Indirect labour	36	100	149
Support staff	23	54	79
Total assembly operations staff	268	734	1,081
Subtotal productive	1,175	3,387	5,491
Administrative and Support Staff	473	1,182	1,615
Total staffing requirements	1,648	4,569	7,106
Ratio of staffing increases	1.00	2.77	4.31
Ratio of plant outputs	1.00	3.00	4.50

TABLE 43

SUMMARY OF TOTAL CAPITAL REQUIREMENTS

ACTUAL MAKE-BUY MIX

(Thousands of U. S. dollars)

Function	Plant Size: 20,000 Units per Year	Plant Size: 60,000 Units per Year	Plant Size: 90,000 Units per Year
(a) With Cost of Administrative and Support Functions Shown Separately			
Productive Functions			
Foundry			
Machinery and equipment	$11,504	$ 26,866	$ 38,361
Building	7,900	16,800	23,800
Inventory	776	2,293	3,497
Total, "permanent" facilities	$20,180	$ 45,959	$ 65,658
Add average investment in tooling	1,210	1,320	1,470
Total, Foundry	$21,390	$ 47,279	$ 67,128
Stamping Plant			
Machinery and equipment	$ 1,426	$ 3,153	$ 5,634
Building	1,050	2,205	3,439
Inventory	304	820	1,772
Total, "permanent" facilities	$ 2,789	$ 6,178	$ 10,845
Add average investment in tooling	619	633	727
Total, Stamping Plant	$ 3,399	$ 6,811	$ 11,572
Machining Operations			
Machinery and equipment	$15,705	$ 40,352	$ 69,690
Building	1,181	3,276	5,471
Inventory	479	1,686	3,197
Total, "permanent" facilities	$17,365	$ 45,314	$ 78,358
Add average investment in tooling	136	376	657
Total, Machining Operations	$17,501	$ 45,690	$ 79,015

TABLE 43

(Continued)

Function	Plant Size: 20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
Assembly Operations			
Machinery and equipment	$ 1,798	$ 3,724	$ 4,814
Building	1,197	2,856	3,728
Inventory	6,327	16,556	20,801
Total, "permanent" facilities	$ 9,322	$ 23,136	$ 29,343
Add average investment in tooling	192	504	732
Total, Assembly Operations	$ 9,514	$ 23,640	$ 30,075
Subtotal, Productive Functions	$51,804	$123,420	$187,790
Administrative and Support Functions			
Office Support and Administrative			
Machinery and equipment	$ 74	$ 163	$ 216
Building	492	1,002	1,368
Total	$ 566	$ 1,165	$ 1,584
Material Handling			
Machinery and equipment	$ 3,050	$ 8,448	$ 12,320
Building	1,028	2,760	4,220
Total	$ 4,078	$ 11,208	$ 16,540
Factory Support			
Machinery and equipment	$ 597	$ 1,809	$ 2,442
Building	980	2,460	3,495
Total	$ 1,577	$ 4,269	$ 5,937
Subtotal, Administrative and Support Functions	$ 6,221	$ 16,642	$ 24,061
Total Capital Requirements	$58,025	$140,062	$211,851

TABLE 43

(Concluded)

Function	Plant Size 20,000 Units per Year	60,000 Units per Year	90,000 Units per Year
(b) With Cost of Administrative and Support Functions Allocated to Production Functions[1/]			
Foundry			
Own capital requirements	$21,390	$ 47,279	$ 67,128
Allocated requirements	2,763	6,757	8,951
Total	$24,153	$ 54,036	$ 76,079
Stamping Plant			
Own capital requirements	$ 3,399	$ 6,811	$ 11,572
Allocated requirements	547	1,082	1,588
Total	$ 3,946	$ 7,893	$ 13,160
Machining Operations			
Own capital requirements	$17,501	$ 45,690	$ 79,015
Allocated requirements	2,202	6,723	11,020
Total	$19,703	$ 52,413	$ 90,035
Assembly Operations			
Own capital requirements	$ 9,514	$ 23,690	$ 30,075
Allocated requirements	709	2,080	2,502
Total	$10,223	$ 25,720	$ 32,577
Total Operations			
Productive Functions	$51,804	$123,420	$187,790
Administrative and Support Functions	6,221	16,642	24,061
Total Capital Requirements	$58,025	$140,062	$211,851

1/ The basis of allocation of Administrative and Support Capital was the proportion of each production function's Facilities and Capital (i.e. Fixed Costs), in the total of these costs for the production function only. These percentages are shown on Table 39.

would be required per unit. Table 42 summarizes staffing requirements and illustrates the fact that requirements for these personnel do not increase in direct proportion to volume.

(4) Administrative and Support Costs per Unit Decrease Significantly as Volume Increases. As shown in Table 41, administrative and support costs would decrease $64 per unit between the 20,000-unit and 90,000-unit volume level. The factors causing this reduction were examined in Chapter VIII.

(5) Improved Utilization of Facilities and Capital Reduces Manufacturing Costs as Volume Increases. Another significant factor in the projected cost reduction is the proration of facility and capital costs for an increased number of production units.

As shown in Table 43, total capital requirements increase from $58 million to $212 million, rather than to the $260 million that would be indicated by a proportionate increase from 20,000 to 90,000 units per year. As a result, facilities and capital costs decrease $125 (Table 41) per unit between the 20,000- and 90,000-unit levels.

In summary, the economies identified previously would amount to $754 per unit between the 20,000- and 90,000-unit volume levels. These savings equal about 20% of the cost of production at the 20,000-unit volume level. Between the 20,000- and 60,000-unit volume levels, the savings are $463 or 12% of the 20,000-unit volume cost.

2. COST SAVINGS = "PROFITS" VARY AMONG PLANTS AT DIFFERENT VOLUME LEVELS

To explore the comparative profitability of tractor manufacturing operations at different volumes, we must turn to the concept of profit centres. Under this concept, a company divides its activities into a logical series of pseudo-independent segments which treat one another as if they were at arm's length, rather than part of the same company. Profit centres can, of course, be as large as divisions or separate companies in conglomerate corporations, or as small as separate plants. How large or small they should be in any real world situation is governed by the relationship of the additional costs of operating profit centres against the anticipated improvement in management responsibility which they can bring about. These additional costs would include the costs of developing valid transfer prices and accounting for costs and revenues in more detail than would otherwise be required.

For the whole tractor company it would be useful to establish four profit centres, corresponding to the four plants one would expect to find -- the foundry, the stamping plant, the machine shop, and the assembly plant. As a whole, they make up a combined profit centre, the tractor manufacturing establishment. By examining each of the plants separately as a profit centre it would be possible to determine which are making profits and which losses, in which area it would be most profitable to make further investments, and whether investments should be made at all in certain plants.

In this study, however, instead of the four plants, we have developed the following breakdown of costs:

Foundry
Stamping plant
Machining operations
Assembly operations

The first two of these correspond to plants; the latter two are not self-contained plant units. The reason for this situation is that costs were collected functionally, rather than in terms of plants. For the first two activities, the functions correspond to the "plant", but for the latter two, the machining operations for an engine or transmission are a "function" and the engine or transmission is completed only when the assembly "function" is added to the machining function. This point is brought out in the first paragraph of Chapter VII, Examination of Assembly Operations. The operations required to assemble major subassemblies, such as the engine or transmission, are "normally performed immediately after machining operations and usually considered part of the engine or transmission building activity".

The analysis of machining operations only, instead of a machine shop or plant which both machines engine and transmission components and assembles finished engines and transmissions, has the effect of transferring a large part of the profit which would be earned by an engine or transmission plant to "Assembly Operations". This is because the "profit" which would result from using a transfer price for either of the components, finished to the level at which they would be used in an assembly plant, is higher than the level relating to the manufacture of the component parts alone. Nevertheless, the analysis of profit centre "profits" will be revealing and give further insight into the decision-making process.

The concept of a profit centre requires a price at which plant A can sell its products to plant B. This "transfer price" is the key question as to the validity of the subsequent profit centre analyses. To the extent that transfer prices approximate market prices, the resulting profit analysis is useful; if the prices are not realistic, however, the whole profitability study is useless.

Within this study, and governed by its internal logic, market prices are available for all parts as set out in Appendix 2. In Table A2-2, the value (at the 60,000-unit volume level) of the "Make Items" is shown for each category of parts for each production volume. These prices were used as the "market price" for the output of the component fabrication operations. What remains to complete the picture is a price at which the whole tractor manufacturing establishment can sell its finished machines. This is shown in Table 44 as the weighted average of the tractors produced. The "suggested retail prices" for the three tractor sizes were constructed by multiplying appropriate average prices per horsepower (taken from the Special Report on Prices of Tractors and Combines in Canada and Other Countries, published by the Commission) by the horsepower taken for each of the three tractor sizes studied herein.

Within this study, it has been assumed that the same tractors are being made, with the same options, in the same mix of sizes, in three plants of 20,000-, 60,000-, and 90,000-unit volume. It is reasonable to postulate, therefore, the same "market price" for components made by the tractor manufacturer and for the finished mid-range tractor itself, regardless of unit volume.

In the real world, of course, the output of a particular plant can sometimes be sold at a different price than the output of a plant producing at another volume level. This can result from such items as transportation economies created by proximity to markets, or special product features. To the extent that such price differences could exist, the cost penalties (or lower profits) associated with a lower-volume plant as against a higher-volume plant might be offset by a higher market price for the component or finished tractor.

The costs of operating the four manufacturing activities were examined in relation to their effect on profitability, against the constant 60,000-unit volume price level for the different group of components selected to be manufactured at each volume level. Thus the number of components selected to be manufactured at each

TABLE 44

DEVELOPMENT OF PRO FORMA MANUFACTURING SELLING PRICE INCLUDING PROFIT, FOR OUTPUT OF TRACTOR FACTORY

	Price (U.S. $)	Relative Number to Suggested Retail Price 3/
Suggested retail price	$6,929 1/	100
Less dealer discounts	(1,871)	(27)
Net selling price to dealer	$5,058	73
Less distribution costs and profits, administrative commercial expenses, etc.	(831)	(12)
Manufacturing price to distributing division	$4,227	61
Less R & D costs (at Deere & Co. level)	(208)	(3)
Manufacturing selling price (exclusive of R & D costs, but including manufacturing profit)	$4,019	58
Rounded to	$4,000 2/	

1/ Prices, representing market level prices in Canada and the United States, for 40, 90, and 130 hp. tractors were developed from data published in Special Report on Prices of Tractors and Combines in Canada and Other Countries, Royal Commission on Farm Machinery, Queen's Printer, Ottawa, 1969, Chapter 5. Prices were constructed from average of prices per horsepower for all diesel tractors sold in Canada in three horsepower ranges by the four leading companies selling tractors in each horsepower range.

Range	Market Share of Four Leading Companies in Range (%)	Their Average Price per Hp. in Range (Can. $)	Hp. of Tractors Studied	Estimated Suggested Retail Price for Each Tractor (Can. $)
35 - 45	76	91.4	40	3,656
70 - 99	80	96.0	90	8,640
100 and over	87	93.1	130	12,103

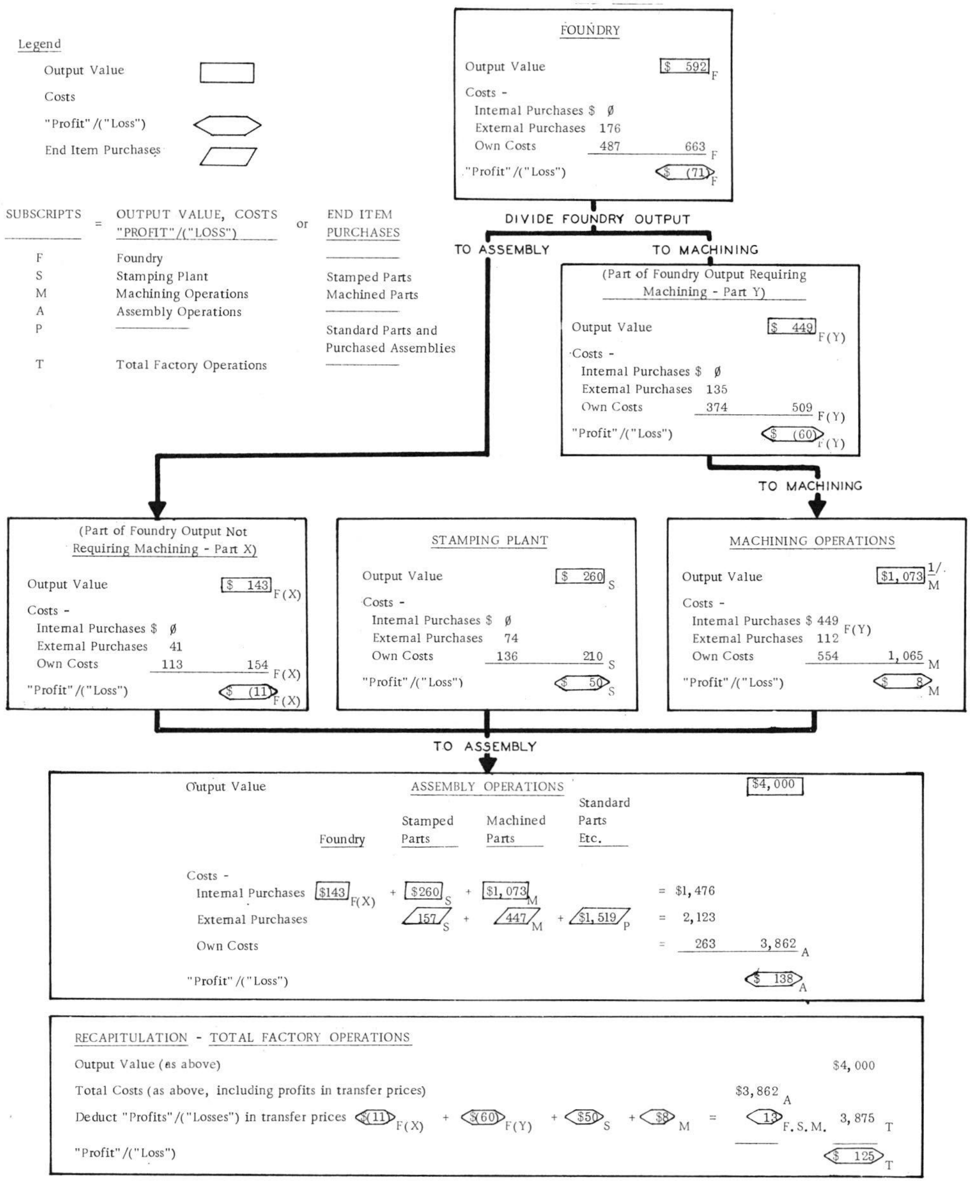
In turn, the average price of these three tractors was developed, weighted according to their proportion in the mix in the plant, as $7,491 (Canadian dollars) or $6,929 (U. S. dollars).

2/ This $4,000 "Manufacturing selling price" is used in Table 45 to develop the difference in profits earned by plants at different volumes.

3/ Relative numbers taken from Figure 1, except R & D costs, taken from Deere & Company Annual Reports.

TABLE 45-1

COMPARISON OF "PROFITS" IN DIFFERENT PROCESSES AT 20, 000-UNIT VOLUME



1/ Calculation of Machined Parts Made at 20, 000-Unit Volume

Value of all Machined Parts (Appendix 2)

	Castings		Forgings		Steel Bars		Tubing		Aluminum		Total
Total	$1, 095 - $143 1/ = $952	+	$261	+	$122	+	$134	+	$21	=	$1, 490

Less Value of Machined Parts "purchased" (Appendix 2)

Total	$197	+	$102	+	$ 41	+	$ 58	+	$19	=	$ 417

Value of Machined Parts "made" (Appendix 2)

Total	$755	+	$159	+	$ 81	+	$ 76	+	$ 2	=	$1, 073

TABLE 45-2

COMPARISON OF "PROFITS" IN DIFFERENT PROCESSES AT 60, 000-UNIT VOLUME

Legend

- Output Value — [rectangle]
- Costs
- "Profit"/("Loss") — [hexagon]
- End Item Purchases — [parallelogram]

SUBSCRIPTS	= OUTPUT VALUE, COSTS "PROFIT"/("LOSS")	or END ITEM PURCHASES
F	Foundry	————
S	Stamping Plant	Stamped Parts
M	Machining Operations	Machined Parts
A	Assembly Operations	————
P	————	Standard Parts and Purchased Assemblies
T	Total Factory Operations	————

FOUNDRY

Output Value		$ 628 F
Costs -		
Internal Purchases	$ ∅	
External Purchases	182	
Own Costs	389	571 F
"Profit"/("Loss")		$ 57 F

DIVIDE FOUNDRY OUTPUT

TO ASSEMBLY — TO MACHINING

(Part of Foundry Output Requiring Machining - Part Y)

Output Value		$ 485 F(Y)
Costs -		
Internal Purchases	$ ∅	
External Purchases	141	
Own Costs	300	441 F(Y)
"Profit"/("Loss")		$ 44 F(Y)

TO MACHINING

(Part of Foundry Output Not Requiring Machining - Part X)

Output Value		$ 143 F(X)
Costs -		
Internal Purchases	$ ∅	
External Purchases	41	
Own Costs	89	130 F(X)
"Profit"/("Loss")		$ 13 F(X)

STAMPING PLANT

Output Value		$ 262 S
Costs -		
Internal Purchases	$ ∅	
External Purchases	70	
Own Costs	91	161 S
"Profit"/("Loss")		$ 101 S

MACHINING OPERATIONS

Output Value		$1, 227 M 1/
Costs -		
Internal Purchases	$ 485 F(Y)	
External Purchases	145	
Own Costs	480	1, 110 M
"Profit"/("Loss")		$ 117 M

TO ASSEMBLY

ASSEMBLY OPERATIONS

	Foundry		Stamped Parts		Machined Parts		Standard Parts Etc.			
Output Value										$4, 000
Costs -										
Internal Purchases	$143 F(X)	+	$262 S	+	$1, 227 M			=	$1, 632	
External Purchases			145 S	+	263 M	+	$1, 420 P	=	1, 828	
Own Costs								=	227	3, 687 A
"Profit"/("Loss")										$ 313 A

RECAPITULATION - TOTAL FACTORY OPERATIONS

Output Value (as above)		$4, 000
Total Costs (as above, including profits in transfer prices)	$3, 687 A	
Deduct "Profits"/("Losses") in transfer prices $130 F(X) + $44 F(Y) + $101 S + $117 M =	(275) F. S. M.	3, 412 T
"Profit"/("Loss")		$ 588 T

1/ Calculation of Machined Parts Made at 60, 000-Unit Volume

Value of all Machined Parts (Appendix 2)

	Castings		Forgings		Steel Bars		Tubing		Aluminum		Total
Total	$1, 095 - $143 1/ = $952	+	$261	+	$122	+	$134	+	$21	=	$1, 490

Less Value of Machined Parts "purchased" (Appendix 2)

Total	$126	+	$ 61	+	$ 32	+	$ 42	+	$ 2	=	$ 263

Value of Machined Parts "made" (Appendix 2)

Total	$826	+	$200	+	$ 90	+	$ 92	+	$19	=	$1, 227

TABLE 45-3

COMPARISON OF "PROFITS" IN DIFFERENT PROCESSES AT 90,000-UNIT VOLUME

Legend

- Output Value — [box]
- Costs
- "Profit"/("Loss") — [hexagon]
- End Item Purchases — [parallelogram]

SUBSCRIPTS =	OUTPUT VALUE, COSTS "PROFIT"/("LOSS")	or END ITEM PURCHASES
F	Foundry	———
S	Stamping Plant	Stamped Parts
M	Machining Operations	Machined Parts
A	Assembly Operations	———
P	———	Standard Parts and Purchased Assemblies
T	Total Factory Operations	———

FOUNDRY

Output Value		$ 691 F
Costs -		
Internal Purchases	$ ∅	
External Purchases	185	
Own Costs	376	561 F
"Profit"/("Loss")		$ 130 F

DIVIDE FOUNDRY OUTPUT — TO ASSEMBLY / TO MACHINING

(Part of Foundry Output Requiring Machining - Part Y)

Output Value		$ 548 F(Y)
Costs -		
Internal Purchases	$ ∅	
External Purchases	144	
Own Costs	292	436 F(Y)
"Profit"/("Loss")		$ 112 F(Y)

TO MACHINING

(Part of Foundry Output Not Requiring Machining - Part X)

Output Value		$ 143 F(X)
Costs -		
Internal Purchases	$ ∅	
External Purchases	41	
Own Costs	84	125 F(X)
"Profit"/("Loss")		$ 18 F(X)

STAMPING PLANT

Output Value		$ 397 S
Costs -		
Internal Purchases	$ ∅	
External Purchases	103	
Own Costs	110	213 S
"Profit"/("Loss")		$ 184 S

MACHINING OPERATIONS

Output Value		$1,458 M 1/
Costs -		
Internal Purchases	$ 548 F(Y)	
External Purchases	194	
Own Costs	526	1,268 M
"Profit"/("Loss")		$ 190 M

ASSEMBLY

ASSEMBLY OPERATIONS

	Foundry		Stamped Parts		Machined Parts		Standard Parts Etc.			
Output Value										$4,000
Costs -										
Internal Purchases	$143 F(X)	+	$397 S	+	$1,458 M			=	$1,998	
External Purchases			10 S	+	31 M	+	$1,377 P	=	1,418	
Own Costs								=	209	3,625 A
"Profit"/("Loss")										$ 375 A

RECAPITULATION - TOTAL FACTORY OPERATIONS

Output Value (as above)		$4,000
Total Costs (as above, including profits in transfer prices)	$3,625 A	
Deduct "Profits"/("Losses") in transfer prices $18 F(X) + $112 F(Y) + $184 S + $190 M =	(504) F.S.M.	3,121 T
"Profit"/("Loss")		$ 879 T

1/ Calculation of Machined Parts Made at 90,000-Unit Volume

Value of all Machined Parts (Appendix 2)

	Castings		Forgings		Steel Bars		Tubing		Aluminum		Total
Total	$1,095 - $143 1/ = $952	+	$261	+	$122	+	$134	+	$21	=	$1,490

Less Value of Machined Parts "purchased" (Appendix 2)

Total	$ 0	+	$ 17	+	$ 10	+	$ 5	+	$ 0	=	$ 32

Value of Machined Parts "made" (Appendix 2)

Total	$952	+	$244	+	$112	+	$129	+	$21	=	$1,458

volume level varies, but the equivalent unit purchase price for each component manufactured (its proxy market price) will not. In this way, a measure of the advantage or disadvantage resulting from the scale of manufacturing becomes evident against the constant market value at the 60,000-unit volume level assumed for the output of the production facility. The details of this examination are shown in Appendix 50 and summarized in Table 45.

Table 45 has three sections, each of which covers "revenues, costs, and profits" at a specific volume level, 20,000, 60,000, or 90,000 units. Each manufacturing activity is shown separately, with arrows designating the flow of the output of components from one facility as an input to another. For example, part of the output of the foundry goes directly to assembly operations, and part to machining operations to be made into items such as engine blocks or transmission cases and gears, which are then sent on to assembly operations. The output of the stamping plant also goes on to assembly operations.

As these flows occur, the output of each facility is valued at transfer prices equal to their outside purchase price at 60,000-unit volume level. These prices are shown in Appendix 2, Table A2-2. The costs of manufacturing the components in each facility are deducted from the value of the output of the facility. The result is the "profit" or "loss" for making the items selected to be made in that facility at that volume.

The assembly operation is the final stage. Its costs consist of the cost of outside purchases, inside purchases made from the other operation areas, and actual assembly costs. These total costs are deducted from the weighted average of the selling prices of the tractors to the distribution division of the company (as established in Table 44).

The final part of each section of Table 45 deducts the "profits" or "losses" shown as being "earned" in the manufacturing activities prior to the assembly operations. This is necessary to reconcile the data collected for "profit center" concept purposes to that necessary for total factory cost evaluation. The result, for each volume level, is a return to the total costs for the actual make-buy mix shown on Table 40. When these costs are deducted from the same transfer price for the mid-range tractor to the distribution division of the company, the total "profit" for the tractor manufacturing operations results. The data shown in Table 45 are shown in more detail in Appendix 50, Tables A50-1, -2, and -3.

In the outside purchases of components actually bought at each volume level, the price differences caused by volume changes are shown in Appendix 50. The basis identified in Table A2-3 is used in Appendix 50, a 7% increase in price between the 60,000- and 20,000-unit volume levels and a 3% decrease between the 60,000- and 90,000-unit volume levels. Thus the purchase-cost advantages and disadvantages relating to volume are included, but the value of what is being made in the manufacturing plants is assumed to be constant. The casting, stamping, machined part or finished tractor made at the 20,000-unit volume level is not worth more because it may cost more to make than at the higher volume levels.

Appendix 50, therefore, provides a basis for comparison of the difference in costs by manufacturing activities against an assumed constant revenue level (the price that would be paid by a manufacturer at the 60,000-unit level who bought all required components instead of making some of them), adjusted only for the difference in the make-buy decisions at the different volume levels. The effect of having chosen the 60,000-unit level as the "price" level against which to examine costs is neutral, as far as the relationships between profitability at the different volume levels are concerned. It does affect the absolute amount of profit (or loss) as explained below.

By choosing the 60,000-unit volume level as set out in Appendix 2 to establish the price level, a "loss" results in the foundry at the 20,000-unit volume against an overall "profit" at the 60,000-unit volume level and greater "profits" at the 90,000-unit volume level. The foundry "loss" at the 20,000-unit volume level could be turned into a "profit" by increasing sufficiently the assumed market value for castings. The addition of 7% to the price level assumed at 20,000-unit volume, raising the "price" of the foundry output to $634 against a cost of $663, however, would still not remove the foundry "loss". It would, however, increase equivalently the "profits" at the 60,000- and 90,000-unit volumes. There would still be relatively the same profit differences among the three volume levels. Moreover, given the constraint of the fixed end-product "price" shown in Table 44, the increase in "profits" in the component manufacturing operations would simply transfer "profits" from the complete tractor (the assembly operation) to the component manufacturing operations. In any case, the decision to have a foundry at 20,000-unit volume was based on the decision to make engines and the overall anticipated profitability of the whole tractor manufacturing complex.

Table 45 was designed as a graphic illustration of the "Profit Center" concept. Each of the four major manufacturing plants was shown as a separate enterprise, and its contributions to total profit examined through use of the "market prices" mentioned earlier.

Figure 1 indicated the following component structure of the wholesale price:

Dealer Price, i.e., Wholesale Price = Production Costs
+ Manufacturing and Assembly Plant Profits
+ General and Administrative Expenses
+ Amortized Development Costs
+ Distribution Costs
+ Wholesale Profit [1]

While this study has examined factory production costs only, with a wholesale price of the completed tractors available it can examine the profits earned in the three manufacturing plants -- the Foundry, the Stamping Plant, and the Machining Operations -- as well as in the Assembly Operations.

The profit earned by each manufacturing operation is contained within the total value of production at "market prices" of the tractor manufacturing facility:

Production Costs as in [1] = Cost of all components if purchased
- Purchase Cost of components determined to be "made" at that particular volume
+ Manufacturing Cost of these components
+ Assembly Costs [2]

At the 60,000-unit volume level, Table 45 (with Appendix A2-2) gives the following data for this equation:

$3,412	=	$3,460	-	$1,632	+	$1,357	+	$227
(A50-2)		(A2-2)		(A2-2)		(Table 45)		(Table 31)

The "profit" resulting from component sourcing decisions can now be expressed (for that volume):

[[Purchase Cost of components determined to be "made] - [Manufacturing Cost of these components]] = ["Profit" resulting from sourcing decisions in all manufacturing categories] [3]

Again, for the 60,000-unit volume level, the same data give the following "profit" result:

$1,632 - $1,357 = $275

For each manufacturing facility (foundry, stamping plant, or machine shop) the following double equation can be shown (for the particular unit volume level):

Cost of purchasing all components of a particular category, e.g. cast, stamped, or machined, whether "bought" or "made"	=	[Cost of actually purchasing components of particular category actually sourced as "bought"] +[Cost of purchasing the rest of the components of particular category actually sourced as "made", price as if they were "bought" instead of "made"]	=	[Cost of actually purchasing components of particular category sourced as "bought"] + [Cost of making rest of the components sourced as "made"] +["profit" resulting from sourcing decision in that manufacturing category]	[4]

For the category of machined parts ("made" and "bought") at the 60,000-unit volume level, the following data are taken from the last section of Table 45:

$1,490 = $263 + $1,227 = $263 + $1,110 + $117

The $117 represents the "profit" created by the decision to machine the group of parts selected at this volume, instead of purchasing them on the market.

The effect of this profit analysis is to distribute the cost differences shown on Table 41 at the selected volumes as "profits" and "profit differences" among the three manufacturing facilities.

This examination exposes the profit to be earned as a result of a fabricating rather than purchasing the "made" parts. For example, the "market price" of all "made" components is $1,632 (from Table 45). The cost of fabricating these components at the

60,000-unit volume is $1,357 and a component fabrication "profit" of $275 results. A similar review can be made for each plant at each volume.

The more significant figures from Table 45 are summarized and compared in Table 46. This table relates "plant profitability" at the various levels and presents an overview of the effect of economies of scale on profitability.

Table 46 shows that the foundry will be $201 more "profitable" for each tractor produced at the 90,000-unit level than at the 20,000-unit level, with $128 or 64% of the cost savings occurring between the 20,000- and 60,000-unit volumes. The stamping plant will increase in "profitability" by $134 between the lowest and highest volume, but a lower percentage of this change, 39% ($51), will occur between the 20,000- and 60,000-unit volumes. The machining operations' "profitability" will improve by $182 at the higher volume over the 20,000-unit volume level, with $109 or 60% occurring between the lowest and mid-point volume levels. The assembly operations' profitability increases by $237 at the 90,000-unit volume level over the 20,000-unit volume level with $175 or 74% of the profitability improvement occurring between the 20,000- and 60,000-unit volume.

It is now possible to calculate projected returns on investment in the four manufacturing "plants" and the tractor manufacturing establishment as a whole, using the previously calculated plant "profitability" levels and the investment costs shown for each plant in the body of the study. The costs on which these "profits" are based assume the borrowing of all capital and include, of course, the cost of capital required, based on a 7.5% cost of capital. These "profits" therefore are the profits the businessman speaks of and pays taxes on, that is entrepreneurial profits after providing for the real or imputed cost of money. If

TABLE 46

COMPARATIVE PROFITABILITY OF

DIFFERENT MANUFACTURING OPERATIONS

(U.S. dollars)

	Unit Profitability At:			Differences in Unit Profitability (Equalling Differences in Unit Costs) Between		
	20,000 Units per Year	60,000 Units per Year	90,000 Units per Year	20,000 and 60,000 Units per Year	60,000 and 90,000 Units per Year	20,000 and 90,000 Units per Year
Operation analyzed						
Foundry	$(71)	$ 57	$130	$128	$ 73	$201
Stamping plant	50	101	184	51	83	134
Machining operations	8	117	190	109	73	182
Assembly operations	138	313	375	175	62	237
Total tractor factory "profit"/("loss")	$125	$588	$879	$463	$291	$754

internal sources of funds are used (e.g. depreciation accounts, retained earnings, or new equity capital), the sophisticated businessman regards them as having been earning, and therefore entitled to, the market rate. Whether the money is actually borrowed externally or transferred internally, the businessman tends to consider the cost of money as a cost before his profits are recorded.

An alternative approach, which will be referred to here as the gross return to capital, views profits as the total return to an enterprise after all costs are deducted, such as materials, labour, and the amortization of the capital equipment used in the business enterprise. According to this view, the cost of borrowing money should be included in the gross return. The businessman's profit concept understates the picture vis-à-vis this view because a part of the gross return to capital is disbursed as interest payments which accounting conventions and taxation policy allow to be treated as expenses, instead of return to capital.

Table 47 shows the total profits at actual make-buy mix for each plant by multiplying the unit plant profit shown on Table 46 by the related 20,000-, 60,000-, or 90,000-unit volume. This "profit" is first shown as a percentage of the total investment required for each plant at each volume, to give the entrepreneurial "profit" rate. The constant 7.5% cost of capital is then added to the entrepreneurial "profit" percentage to secure the gross return to capital.

In business terms, the foundry changes the level of its return on investment before taxes from a 5.8% rate of "loss" at 20,000-unit volume to 15.4% "profit" rate at 90,000-unit volume. The stamping plant change is from 25.3% to 125.8% rate of "profit", while machining operations move from .8% to 19.0% rate

TABLE 47

DIFFERENCES IN RETURN ON INVESTMENT:

PRODUCTION PLANTS AT DIFFERENT VOLUMES

(U.S. dollars)

	20,000 Units per Year (Thousands)	%	60,000 Units per Year (Thousands)	%	90,000 Units per Year (Thousands)	%
Foundry						
Gross "profit" before taxes	$(1,400)		$ 3,420		$11,700	
Investment (Table 43)	$24,153		$54,036		$76,079	
Return on assets (before taxes)						
- entrepreneurial concept		(5.8)		6.3		15.4
- gross return		1.7		13.8		22.9
Stamping Plant						
Gross "profit" before taxes	$ 1,000		$ 6,060		$16,560	
Investment (Table 43)	$ 3,946		$ 7,893		$13,160	
Return on assets (before taxes)						
- entrepreneurial concept		25.3		76.8		125.8
- gross return		32.8		84.3		133.3
Machining Operations						
Gross "profit" before taxes	$ 160		$ 7,020		$17,100	
Investment (Table 43)	$19,703		$52,413		$90,035	
Return on assets (before taxes)						
- entrepreneurial concept		.8		13.4		19.0
- gross return		8.3		20.9		26.5
Assembly Plant						
Gross "profit" before taxes	$ 2,760		$18,780		$33,750	
Investment (Table 43)	$10,223		$25,720		$32,577	
Return on assets (before taxes)						
- entrepreneurial concept		27.0		73.0		103.6
- gross return		34.5		80.5		111.1
Total Establishment						
Gross "profit" before taxes	$ 2,500		$ 35,280		$ 79,110	
Investment (Table 43)	$58,025		$140,062		$211,851	
Return on assets (before taxes)						
- entrepreneurial concept		4.3		25.2		37.3
- gross return		11.8		32.7		44.8

of "profit". The assembly plant "profit" changes from 27.0% to 103.6% and the whole establishment from 4.3% to 37.3%.

The analysts felt that, while the slope of the stamping plant "profit" rate between the different volume levels was reasonable, the absolute levels were probably somewhat higher than would be experienced in industry. Several factors may have contributed to this apparent aberration. The first is that the average "outside", alternative price for stampings, at one-third the price of the stamping as a replacement part, may have been too high for this particular parts category. Stampings for replacement are primed and painted and the original stamping would not have had to bear this charge except when the whole tractor was assembled. The removal of this cost would probably reduce stamping outside prices by about 10% to bare-metal levels. In any case, as noted earlier, the profitability of the complete tractor manufacturing operations would not be affected.

When the 7.5% "cost of capital employed" is added back to each "profit" or "loss" percentage, all operations become "profitable", the foundry's "profit" ranging from 1.7% before taxes at 20,000-unit volume to 22.9% at 90,000-unit volume. Similarly, the "profit" rate for the stamping plant becomes 32.8% before tax at 20,000-unit volume and 133.3% at 90,000-unit volume. The machining operations change to 8.3% and 26.5% before taxes and the assembly plant rates become 34.5% and 111.1%. The rates for the whole tractor manufacturing establishment become 11.8% and 44.8%.

What is first clear from these "return on assets employed" data is the effect of the very large "cost reduction" or "profit improvement" occurring as the production volume increases. Not only does the possible return on assets employed increase, but also the absolute volume of potential profits grows by orders of magnitude ranging from almost 17 to 1 for the stamping plant to more than 100 to 1 for the machine shop. For the foundry, the move is from a "loss" position at 20,000-unit volume, but the profit at 90,000-unit volume is almost three and a half times greater than at 60,000-unit volume. The large absolute profits that can be generated at higher volumes are a further indication of the economies of scale associated with tractor manufacturing at higher volume levels. The whole tractor manufacturing establishment's profits increase more than 30 times, while the assets needed to produce the tractors increase only four times.

The outstanding rate of return on capital in the assembly operations at all volumes should be put into appropriate perspective.

"Profit" rates earned in the parts manufacturing operations (foundry, stamping plant, and machining operations) appear to reduce the "profit" rate available if manufacturing were limited to assembly operations only. The explanation for the high profit rate attributed to assembly operations lies largely in the fact that we are not considering an assembly plant as such, but the total operations concerned with assembly in the whole tractor manufacturing establishment. Ordinarily an assembly plant does not assemble an engine, transmission, or axle, because these items are best moved and stored after being assembled adjacent to the machining area. Their outer cases form the best protection for the critical inner parts.

For purpose of computing costs, however, any assembly operation, regardless of where it would be located, was classified as such. Such a cost distribution effectively transfers to the assembly operations the additional profit which a manufacturing plant would earn if it sold a finished engine, transmission, or axle to a plant which only assembled the tractor.

The assembly profits, of course, also reflect the suggested retail prices for the mix of tractors, averaging $6,929. To the extent that this price is high because North American pricing standards for tractors may be high, the apparent profit potential in tractor assembly is further increased.

3. CERTAIN COSTS VARY SIGNIFICANTLY BETWEEN MODEL SIZES

During the study, manufacturing costs for the three model sizes examined were not segregated. To provide an approximation of such a breakdown, each of the major cost elements was reviewed at the 60,000-unit volume level, and the difference for each model was estimated. Table 48 summarizes the results of this examination and Appendix 51 contains the details.

TABLE 48

PROJECTION OF MODEL COST DIFFERENTIALS

(U.S. dollars)

	Model Size		
	Low HP (35 - 45 HP)	Medium HP (80 - 100 HP)	High HP (125 - 135 HP)
Purchased components	$1,358	$1,828	$2,400
Foundry costs	309	620	1,066
Stamping costs	145	163	184
Machining costs	580	623	764
Assembly costs	209	231	268
Total unit costs	$2,601 Diesel	$3,465	$4,682
	($2,401 Gasoline)		
Cost per horsepower	$65	$39	$36
(Assumed horsepower)	(40)	(90)	(130)

Unit costs for the three models vary most significantly in the area of materials costs and those items allocated on the basis of materials costs. Labour costs differ only to a limited extent. The labour required for making or assembling components is governed more by the number of pieces handled and the operations performed than by their size or weight. Facilities and capital costs were prorated on the basis appropriate to the particular process being examined. Administrative and support costs were allocated as a percentage of the total of other manufacturing costs.

Examination of the cost differences indicates that the diesel version of the low-powered model would cost about $900 less than the medium, or base, model. The high-powered model would cost about $1,200 more. The cost per horsepower of the three sizes decreases as the size of the tractor increases, from $65 per horsepower for the small tractor to $39 per horsepower for the mid-range model, to $36 per horsepower for the largest machine. The cost per horsepower of the largest machine is increased by the fact that its assumed volume is low (6,000 units per year) and it must carry the costs of particular setup operations. These results are approximations only, but indicate that it costs less per horsepower to build a large tractor than a small one.

4. SHORT-TERM VOLUME FLUCTUATIONS INCREASE LABOUR COSTS

The effect of short-term volume fluctuations on unit costs was projected in two ways. This projection was made on the assumption that overtime and temporary layoffs would be used to compensate for varying short-term labour requirements, first on the assumption that volume fluctuated on both sides of a standard production rate, and secondly that there was a continuing change, in one direction, either up or down, because of the actual market in the annual period being significantly different from that predicted.

In actual practice, long periods of increased production would require the addition of new employees while decreased production on a continuing basis would require a more or less permanent layoff. The investment required to hire and train these personnel would be lost if subsequent slack periods necessitated their release.

The cost per unit for each of the major cost factors at volumes 20% above and below the nominal volume was determined, and these costs are summarized in Table 49.

Many material costs would not change significantly as a result of temporary shifts in volume anticipated to be compensated for by subsequent shifts in the other direction. Off-the-shelf items would continue to be purchased under the same price contracts or in the same order quantities. The frequency of delivery would be adjusted to meet the changes in demand. For any item custom made for the tractor manufacturer, however, volume reductions run into the problem of long- and short-term commitments made to the vendor, to allow him to synchronize his production with that of the tractor manufacturer. Volume increases run into the inflexibility of the vendor supply line, so that, unless the increase is balanced by a previous or subsequent decrease, costs will be pushed higher. Administrative costs for production control, purchasing, and traffic (transportation) tend to increase as volume shifts from what was originally planned. If production were reduced, labour costs per unit would increase as a result of supplemental unemployment benefits paid to employees who were laid off because of underutilization of those employees who could not be laid off conveniently. Supplemental unemployment

TABLE 49

PROJECTION OF UNIT COSTS

WITH VOLUME CHANGES IN PLANTS FACILITIZED AT DIFFERENT VOLUMES

(U.S. dollars)

	16,000 Units per Year (20% less)	20,000 Units per Year (base)	24,000 Units per Year (20% more)	48,000 Units per Year (20% less)	60,000 Units per Year (base)	72,000 Units per Year (20% more)	72,000 Units per Year (20% less)	90,000 Units per Year (base)	108,000 Units per Year (20% more)
Variable Costs									
Materials	$2,485	$2,486	$2,485	$2,225	$2,225	$2,225	$1,900	$1,900	$1,900
Labour	449	398	407	436	385	394	470	416	425
Operating expenses	172	145	128	160	135	119	175	147	129
Administrative and support	349	279	232	288	231	192	269	215	179
Variable costs	$3,455	$3,307	$3,252	$3,109	$2,976	$2,930	$2,814	$2,678	$2,633
Fixed Costs									
Facilities	$ 495	$ 395	$ 330	$ 367	$ 293	$ 245	$ 370	$ 297	$ 247
Capital	216	173	144	179	143	119	183	146	122
Fixed costs	$ 711	$ 568	$ 474	$ 546	$ 436	$ 364	$ 553	$ 443	$ 369
Total unit cost	$4,166	$3,875	$3,726	$3,655	$3,412	$3,294	$3,368	$3,121	$3,002

benefit costs vary widely depending on legislative and contractual requirements, duration of layoff period, and other factors. During this examination, the impact on the firm for these costs was estimated at half of the wage normally paid the employees laid off. If output were increased, labour costs would be increased by overtime premiums. Details of labour cost projections and other calculations appear in Appendix 52.

The costs examined under the heading "Operating Expenses" tend to be more fixed than variable in the short term. For this reason, costs per unit increase with a decrease in volume and vice versa. Administrative and support, facility, and capital costs are either independent of temporary volume fluctuations or move much less than the percentage of fluctuation. Therefore, a short-term increase in production also reduces the allocation of these costs per unit. It is important to note that these fluctuations will balance out if actual total annual volume is equal to that planned. On the other hand, the increases in labour costs are not self-correcting, but represent a real cost penalty for volume fluctuation.

Of particular interest in Table 49 are the two cost estimates for plants producing at the 72,000-unit volume level. One estimate is derived from the 60,000-unit volume plant, with its output increased 20%; the other is derived from the 90,000-unit plant operating at 20% below planned capacity. The plant which is operating above capacity has unit costs of $3,294, while the plant operating below capacity has costs of $3,368 at the same volume. The $74 penalty cost difference, or 2.2%, clearly shows the problem of operating a plant below its planned capacity.

In summary, temporary volume fluctuations create excess costs. Offsetting savings in fixed costs may be achieved only if the total volume increases.

X

EXAMINATION OF OPPORTUNITIES FOR REDUCING MANUFACTURING COSTS THROUGH DESIGN IMPROVEMENT

Production economies can be achieved through reducing the number of variations of the same functional component. The study described in the following paragraphs was made to identify opportunities for increasing component standardization through basic design changes.

1. SELECTED TRACTOR SUBGROUPS AND COMPONENTS WERE EXAMINED

This study consisted of an analysis of selected tractor subgroups and components -- engine, power train, transmission, differential, and final drive.

The tractor design requirements were investigated to identify areas in which these constraints could be satisfied with a reduced number of types of components. Subgroups and components not directly investigated were assumed to have similar potential for standardization. Where possible, the method of achieving standardization was indicated.

The study was general in nature, and no specific design work was done, nor was economic evaluation made of the findings. Further, no investigation was made to determine the extent to which manufacturers may have already taken advantage of improvement opportunities.

Study of variations in design parameters was accomplished with analytical techniques that permitted introduction of changes in parameters, materials, and production techniques. The analytical approach was based on the function of the component or subgroup rather than on its size or appearance. The engineering equations were structured to ensure that functional requirements were satisfied. The tractor subdivides conveniently into subgroups on a functional basis, and a synthesized mathematical model was readily prepared as the basis for analysis.

The tractor sizes were analyzed by one series of equations. The tractors were considered to be geometrically identical; configuration and design do not change significantly as a result of size increase alone. If standardization is to be achieved, this geometric identity must be accomplished.

Detailed descriptions of analytical techniques and findings can be consulted in the complete technical report, which is contained in a separate volume and filed with the Commission's archival material.

2. A MAJOR OPPORTUNITY FOR STANDARDIZATION EXISTS IN THE EQUIPMENT THAT IS RELATED TO THE OPERATOR

Inspection of the three tractor sizes reveals a similarity in the operator stations and a major opportunity for standardization. Parts and components related to the operator were virtually identical on all tractors and, from a design standpoint, are intended to accommodate persons with the same physical characteristics. Examples of such operator-related components are the steering wheel, seat, control levers, and instruments.

The main difference in operator stations is that the larger tractors, with better positioning of the elements, provide more space for the operator. Making a standard unit, or pod, of the operator stations would achieve commonality between the components involved as well as with the assembly operation.

3. A MAJOR OPPORTUNITY FOR STANDARDIZATION WAS INDICATED BY AN ANALYSIS OF ENGINE CHARACTERISTICS

An extensive examination was made of engine design characteristics. The same considerations used in it would apply to intermediate engine types required for the full range of tractor sizes. This examination identified the characteristics that govern component design and explored a wide range of combinations of these characteristics. A set of three particular horsepower engines was selected for examination.

(1) Standardization of Cylinder Bore and Minimization of Stroke Variation Would Result in Significant Improvements. A number of theoretical engine designs with standard cylinder bores and minimum stroke variations were examined. These designs used increased numbers of cylinders and supercharging to achieve increases in horsepower.

Standardizing on a single bore size makes possible the use of common pistons, rings, and piston pins.

In addition, since the displacement per cylinder and the engine speed were held about equal for all engines, components related to the cylinder heads could be standardized. These components include valves, valve springs, rocker arms, and valve covers.

A shortcoming of the combination of supercharged with naturally aspirated engines results from the higher cylinder pressures of the supercharged engines. These higher pressures require stronger pistons, pins, and rings to provide the same life expectancy. To standardize these components, a material of higher quality would have to be used for the entire line. Stronger rods and bearings would also probably be required.

The advantages of the designs examined could probably be achieved through the combination of small ranges of bore sizes and stroke lengths. Small variations in bore size could be achieved economically by replaceable wet cylinder liners or by overboring cast-in-block cylinder walls, as long as the block design provides sufficient wall thickness for the maximum bore.

(2) Standardization Based on a Three-Cylinder Engine Module Can Be Projected from Data Obtained in the Study. Data describing the three engines constructed around this modular concept are presented in Table 50.

TABLE 50

THREE-CYLINDER ENGINE MODULE SPECIFICATIONS

	Specified Horsepower		
Item	50 - 55 HP	85 - 95 HP	120 - 135 HP
Number of cylinders	3	6	6
Mean effective pressure (PSI)	110	90	130
Bore diameter (inches)	4.125	4.125	4.125
Stroke length (inches)	4.32	4.53	4.59
Cylinder volume (cubic inches)	57.8	60.7	61.3
Engine volume (cubic inches)	173.5 Unsupercharged	364 Unsupercharged	368 Supercharged

The three-cylinder 50-55 hp. engine forms the base module. The 85-95 hp. engine consists of two 50-55 hp. modules, slightly detuned by a lower cylinder pressure but using increased stroke to keep the bore-to-stroke ratio below unity. The 120-135 hp. engine is essentially an 85-95 hp. engine supercharged by an exhaust-driven turbo-supercharger.

The cylinder block casting for the three engines is made from modular pattern equipment, comprised of a basic three-cylinder section and a front and rear section. The front section carries the gear train for the camshaft and accessory drives, while the rear section includes provisions for the attachment of the engine to the transmission.

Cylinder heads for all engines are interchangeable, assuming a pushrod-operated, overhead-valve design. The basic cylinder head is made as a single unit for the three-cylinder engine and is used in pairs for the six-cylinder engines. Since the individual cylinder volume for all engines is nearly the same, valve sizes as well as diesel fuel injectors and their related hardware can be identical for all engines.

Crankshafts and camshafts for the three- and six-cylinder engines would be unique to the engine because of the differences in the number of cylinders and firing order.

Pistons and related parts, connecting rods, crankpins, and main bearings would be sized for the requirements of the highest cylinder pressure and would be identical for all engines.

4. STUDY OF THE TRANSMISSION TORQUE AND SHAFT DIAMETER REQUIREMENTS FOR THE THREE SIZES OF TRACTORS INDICATED THAT MODULAR TRANSMISSION DESIGN WOULD BE POSSIBLE

Data extracted from the computer analysis of transmission design requirements indicate that these requirements can be made to overlap between horsepower models. For example, transmission torque and shaft diameter characteristics are very similar for the following models and ranges:

50-55 hp. - First through fifth gears
85-95 hp. - Third through seventh gears
120-135 hp. - Fourth through eighth gears

These overlaps are illustrated in Table 51.

For example, compare shaft sizes for 50-55 hp., first gear; 85-95 hp., third gear; and 120-135 hp., fourth gear. Shaft sizes are .937, .926, and .955 inches, with a maximum difference of .029 inches.

The over-all transmission design can be completed for the three horsepower ranges reviewed in this manner:

> Add a sixth, seventh, and eighth gear to complete the transmission for the 50-55 hp. tractor.

TABLE 51

COMPARISON OF TRANSMISSION TORQUE AND OUTPUT SHAFT DIAMETERS

Gear - Torque

50 - 55 HP		85 - 95 HP		120 - 135 HP	
Gear Selection	Torque (inch - pounds)	Gear Selection	Torque (inch - pounds)	Gear Selection	Torque (inch - pounds)
				1st	30,469.10
		1st	20,847.30	2nd	22,851.80
		2nd	15,635.50	3rd	17,138.90
1st	12,141.80	3rd	11,726.60	4th	12,835.10
2nd	9,106.36	4th	878.91	5th	9,597.76
3rd	6,829.77	5th	6,566.89	6th	7,198.32
4th	5,114.74	6th	4,925.17	7th	5,370.18
5th	3,824.67	7th	3,674.33	8th	3,999.07
6th	2,868.50	8th	2,736.20		
7th	2,140.00				
8th	1,593.61				

Gear - Shaft Size

Gear Selection	Output Shaft Diameter (inches)	Gear Selection	Output Shaft Diameter (inches)	Gear Selection	Output Shaft Diameter (inches)
				1st	1.274
		1st	1.122	2nd	1.157
		2nd	1.020	3rd	1.051
1st	.937	3rd	.926	4th	.955
2nd	.851	4th	.841	5th	.867
3rd	.774	5th	.763	6th	.787
4th	.702	6th	.694	7th	.714
5th	.638	7th	.629	8th	.647
6th	.579	8th	.570		
7th	.525				
8th	.476				

Add a first and second gear and an eighth "over-drive" to make the 85-95 hp. transmission.

Add a first, second, and third gear to make the 120-135 hp. transmission.

Actual transmission design is much more complex than the foregoing comments would suggest. However, the analysis indicates that a significant possibility for manufacturing simplification exists.

5. <u>SOME OPPORTUNITIES FOR STANDARDIZATION OF POWER-TRAIN GEARS WERE INDICATED</u>

The parts selected for detailed study and comment were the transmission input gear, the differential pinion gear, and the final drive input gear (sun pinion). The study examined the interrelationship of variables in gear design and in manufacturing quality to identify standardization opportunities among these gears. The variables examined were: gear pitch, gear face width, gear diameter, gear material in terms of endurance stress limit, and gear tooth profile error.

The mathematical analysis of the gear tooth was made by holding four of the variables fixed and computing the effect on the margin of safety of a range of values assigned to the fifth variable.

Standardization was considered to be achieved when manipulation of a fifth variable resulted in a gear design that would satisfy the requirements of all three tractor sizes. This analysis indicates that limited standardization of transmission input gears can be achieved by manipulating diameter, material, and/or tooth profile error. Of these variables, material is easiest to change since the same production operations, except possibly heat treating, would be used. That is, it is indicated that the design of certain gears could be common, with higher performance requirements met through the use of stronger materials.

TABLE 52

ESTIMATE OF POTENTIAL ANNUAL SAVINGS

THROUGH DESIGN STANDARDIZATION IN THE 60,000-UNIT PLANT

Source of Saving	Range of Estimated Saving	Average Value
1. Through the use of standard three-cylinder module		
Labour[1/]		
Foundry	40,000 - 50,000	
Machining	50,000 - 75,000	
Assembly	175,000 - 200,000	
Support areas	50,000 - 75,000	
Annual total	$ 315,000 - 400,000	$ 357,000
Capital		
Tooling	$ 400,000 - 460,000	
Machinery	500,000 - 1,000,000	
Warehouse space	100,000 - 200,000	
Inventories	250,000 - 300,000	
Total reduction	$1,250,000 - 1,960,000	$1,605,000
Purchased Components		
Price differential	$ 300,000 - 400,000	$ 350,000
2. Through the use of standard transmission module and gear standardization		
Labour[1/]		
Machining	$ 15,000 - 20,000	
Assembly	100,000 - 125,000	
Other	30,000 - 40,000	
Annual total	$ 145,000 - 185,000	$ 162,000
Capital		
Tooling	$ 75,000 - 100,000	
Machinery and space	250,000 - 300,000	
Total	$ 325,000 - 400,000	$ 362,000

Total Annual Savings Potential

Labour[1/] ($357,000 + $162,000)	$ 517,000
Capital[2/] (Tooling $170,000 + Other $300,000)	470,000
Purchased Components	350,000
Total Savings	$1,337,000

Per Unit Savings $\frac{\$1,337,000}{60,000}$ = $20 - $25 per unit

See notes on next page.

Notes to Table 52:

1/ Includes cost of fringe benefits.

2/ Tooling amortized over three years (517,000 ÷ 3).
Other capital amortized over five years (1,500,000 ÷ 5).

In summary, there appear to be significant opportunities for standardizing tractor components while maintaining or improving performance. The appropriate next step in exploring these opportunities is to evaluate their effect on manufacturing costs.

Table 52 provides a broad range of estimated savings available to a company which adopted design standardization within its manufacturing operations. Using the midpoint of the range for the savings, the tractor manufacturer at 60,000 units per annum would save about $20-25 a unit.

Thus, the company which makes use of the possibilities of design standardization is able to secure significant savings over the company which regards the design of each major tractor group as completely separate from the others. The $20-25 a unit at 60,000-unit volume, while a small saving on each tractor, would increase total profits by $1.2 to $1.5 million.

APPENDICES

TABLE A1-1
COMPONENTS SELECTED FOR DETAILED ANALYSIS

Parts Description (Quantity)	"Estimated" Manufacturer's Cost per Piece	Value Of Parts By Processes Analyzed (U. S. Dollars)						
				Machining Only				
		Casting Only	Casting and Machining	Casting	Forging	Bar Stock	Aluminum	Stampings
Transmission Case*	$97. 90	$	$97. 90	$	$	$	$	$
Cylinder Block*	69. 15		69. 15					
Crankshaft*	59. 40				59. 40			
Clutch Housing*	55. 10		55. 10					
Cylinder Head*	44. 25		44. 25					
Fender (2)	41. 45							82. 90
Housing - Rear Axle (2)	35. 30		70. 60					
Housing - Front Axle	30. 35		30. 35					
Rockshaft Housing*	29. 75		29. 75					
Support	23. 15	23. 15						
Cast Wheel Disk (2)	18. 50		37. 00					
Flywheel**	16. 90		16. 90					
Front Plate Support	16. 35	16. 35						
Hood	15. 60							15. 60
Differential Housing	14. 30	14. 30						
Oil Pan*	13. 95		13. 95					
Pivot Bracket	13. 05	13. 05						
Rear Axle Shaft (2)	12. 90				25. 80			
Countershaft	12. 05				12. 05			
Harmonic Damper	10. 15			10. 15				
Oil Pump	9. 45			9. 45				
Brake Plate (2)	8. 60		17. 20					
Clutch Cover	7. 55		7. 55					
Final Drive Shaft (2)	7. 50			15. 00				
Camshaft	7. 10				7. 10			
Side Frame	6. 95							6. 95
Side Frame	6. 90							6. 90
Gear	6. 70	6. 70						
Gear	6. 55	6. 55						
Pump Support	6. 40		6. 40					
Cover with Tool Box	6. 40							6. 40
Intake Manifold	5. 90		5. 90					
Gear	5. 60	5. 60						
Exhaust Manifold	5. 35		5. 35					
Connecting Rod (6) **	5. 20				31. 20			
Brake Valve Housing	5. 10	5. 10						
Gear	5. 05			5. 05				
Clutch Plate	5. 00		5. 00					
Timing Gear Cover	4. 90							4. 90
Gear	4. 60	4. 60						

TABLE A1-1 (Continued)

Parts Description (Quantity)	"Estimated" Manufacturer's Cost per Piece	Value Of Parts By Processes Analyzed (U. S. Dollars)						
		Casting Only	Casting and Machining	Machining Only				Stampings
				Casting	Forging	Bar Stock	Aluminum	
Water Manifold	$ 4.55	$	$ 4.55	$	$	$	$	$
Quill - PTO	4.55	4.55						
Control Support	4.55							4.55
Clutch Plate	4.35		4.35					
Pedal Bracket	4.20	4.20						
Gear	4.00				4.00			
Pinion	4.00	4.00						
Starter Gear **	3.90					3.90		
Operator Shield (2)	3.80							7.60
Cylinder Liner (6) **	3.80			22.80				
Cowl	3.80							3.80
Platform	3.70							3.70
Planet Pinion (6)	3.55			21.30				
Piston Cover	3.40	3.40						
Pinion	3.35	3.35						
Drum	3.30			3.30				
PTO Gear	3.30			3.30				
Cam	3.30	3.30						
Engine Fan	3.20							3.20
Drum (2)	3.20			6.40				
Pinion	3.00	3.00						
Reverse Collar	2.95	2.95						
Low and High Collar	2.95	2.95						
Battery Box	2.95							2.95
Hub (2)	2.90		5.80					
Grille (2)	2.90							5.80
Rockshaft Cover	2.85							2.85
Front Grille Screen	2.80							2.80
Fan Shroud	2.75							2.75
Oil Seal Housing **	2.70			2.70				
Shifter	2.70	2.70						
Oil Cooler Body	2.60	2.60						
Piston (6) **	2.60						15.60	
Cam	2.55	2.55						
Rocker Arm Cover	2.35							2.35
Crankshaft Gear **	2.25				2.25			
Pump Shaft	2.15					2.15		
Camshaft Gear **	2.15		2.15					
Hood Baffle	2.10							2.10

TABLE A1-1 (Concluded)

Parts Description (Quantity)	Manufacturer's Cost per Piece	Value Of Parts By Processes Analyzed (U.S. Dollars) Casting Only	Casting and Machining	Machining Only: Casting	Machining Only: Forging	Machining Only: Bar Stock	Aluminum	Stampings
Front Gear	$ 2.05	$ 2.05	$	$	$	$	$	$
Brake Disc (2)	2.05							4.10
Shifter	1.95	1.95						
Pedal	1.85	1.85						
Shifter	1.85	1.85						
Extension (2)	1.75							3.50
Clutch Fork	1.45			1.45				
Thermostat Housing (2) **	1.00						2.00	
Extension (2)	.95							1.90
Water Pump Impeller **	.95		.95					
Flywheel Pin (3) **	.70					2.10		
Hub Cap (2)	.55			1.10				
Rocker Arm - Intake (6)	.35							2.10
Rocker Arm - Exhaust (6)	.35							2.10
Total Cost Per Process		$142.65	$530.15	$102.00	$141.80	$ 8.15	$17.60	$181.80
Rounded Numbers Used		$143	$530	$102	$142	$ 8	$18	$182
Number of Components	93	25	21	12	7	3	2	23

* Analyzed components machined on production lines, see Appendix 21.

** Analyzed components that would be purchased at 20,000-unit volume.

TABLE A2-1

CLASSIFICATION OF ALL COMPONENTS REQUIRED FOR MANUFACTURE OF MID-RANGE TRACTOR ANALYZED BY MATERIAL

CHANGE IN NUMBER OF COMPONENTS MADE-BOUGHT AT SELECTED ANNUAL VOLUMES

All Components		20,000 Units				60,000 Units				90,000 Units			
		Quantity			Per Cent	Quantity			Per Cent	Quantity			Per Cent
Material Classification	Total Items	Buy Items	Make Items	Analyzed Items	Analyzed vs. Make	Buy Items	Make Items	Analyzed Items	Analyzed vs. Make	Buy Items	Make Items	Analyzed Items	Analyzed vs. Make
Castings	149	45	104	53	51%	25	124	58	47%	-	149	58	39%
Forgings	24	12	12	5	42	8	16	7	44	5	19	7	37
Sheet Metal (Stampings)	222	75	147	23	16	61	161	23	14	19	203	23	11
Steel Bars	96	59	37	1	3	39	57	3	5	5	91	3	3
Tubing	113	65	48	-	-	43	70	-	-	11	102	-	-
Aluminum	4	3	1	-	-	1	3	2	67	-	4	2	50
Standard Parts (purchased)	1,311	1,311	-	-	-	1,311	-	-	-	1,311	-	-	-
Purchased Assemblies	54	54	-	-	-	54	-	-	-	54	-	-	-
Total	1,973	1,624	349	82	23%	1,542	431	93	22%	1,405	568	93	16%

TABLE A2-2

CHANGE IN VALUE OF COMPONENTS MADE-BOUGHT AT SELECTED ANNUAL VOLUMES

Manufacturer's Base Cost

Expressed in Terms of Outside Purchase Price Anticipated at 60,000-unit Volume for Volume Needed for Mid-Range Tractor Analyzed

(U.S. Dollars)

All Components			20,000 Units				60,000 Units				90,000 Units			
	Total Value		Value			Per Cent	Value			Per Cent	Value			Per Cent
Material Classification	Cost	Per Cent	Buy Items	Make Items	Analyzed Items	Analyzed vs. Make	Buy Items	Make Items	Analyzed Items	Analyzed vs. Make	Buy Items	Make Items	Analyzed Items	Analyzed vs. Make
Castings	$1,095	31.7%	$ 197	$ 898	$ 729	81%	$ 126	$ 969	$ 775	80%	$ -	$1,095	$ 775	71%
Forgings	261	7.5	102	159	109	69	61	200	142	71	17	244	142	58
Sheet Metal (Stampings)	407	11.8	147	260	182	70	145	262	182	69	10	397	182	46
Steel Bars	122	3.5	41	81	2	3	32	90	8	9	10	112	8	7
Tubing	134	3.9	58	76	-	-	42	92	-	-	5	129	-	-
Aluminum	21	.6	19	2	-	-	2	19	18	94	-	21	18	86
Standard Parts (purchased)	929	26.8	929	-	-	-	929	-	-	-	929	-	-	-
Purchased Assemblies	491	14.2	491	-	-	-	491	-	-	-	491	-	-	-
Total	$3,460	100.0%	$1,984	$1,476	$1,022	69%	$1,828	$1,632	$1,125	69%	$1,462	$1,998	$1,125	56%
Per Cent Make-Buy Mix			57%	43%			53%	47%			42%	58%		

TABLE A2-3

EFFECT ON PURCHASING COSTS OF VOLUME CHANGE
AT CONSTANT AND ACTUAL MAKE-BUY MIXES

Estimated Difference in Cost	Constant Make-Buy Mix	
	20,000 Units	90,000 Units
Base Cost of Components	$1,828	$1,828
Per Cent	+7%	-3%
Cost	$ +128	$ -55
Net Cost of Purchased Parts	1,956	1,773
	Actual Make-Buy Mix	
Base Cost of Components	$1,984	$1,462
Per Cent	+7%	-3%
Cost	$ +139	$ -44
Net Cost of Purchased Parts	2,123	1,418

TABLE A2-4

VALUE OF PURCHASED COMPONENTS REQUIRED
AT DIFFERENT VOLUMES, SHOWING SEPARATE EFFECT OF VOLUME AND MAKE-BUY DECISION

	20,000 Units			60,000 Units			90,000 Units		
	Number	No Volume Price Adj., $U.S.	With Volume Price Adj., $U.S.	Number	No Volume Price Adj., $U.S.	With Volume Price Adj., $U.S.	Number	No Volume Price Adj., $U.S.	With Volume Price Adj., $U.S.
PURCHASED COMPONENTS									
Constant Items - (No Make-Buy Decision)									
Standard Parts	1,311	$ 929	$ 994	1,311	$ 929		1,311	$ 929	$ 901
Purchased Assemblies	54	491	525	54	491		54	491	476
Constant Items	1,365	$1,420	$1,519	1,365	$1,420		1,365	$1,420	$1,377
Items with Make-Buy Decisions									
Castings	45	$ 197	$ 212	25	$ 126		--	$ --	$ --
Forgings	12	102	109	8	61		5	17	16
Stampings	75	147	157	61	145		19	10	10
Steel Bars	59	41	44	39	32		5	10	10
Tubing	65	58	62	43	42		11	5	5
Aluminum	3	19	20	1	2				
Items with Make-Buy Decisions	259	$ 564	$ 604	177	$ 408		40	$ 42	$ 41
Total Purchased Components	1,624	$1,984	$2,123	1,542	$1,828	$1,828	1,405	$1,462	$1,418

TABLE A3-1
MOLDING LINE LOAD REQUIREMENTS
CONSTANT MAKE-BUY MIX

Part Name	Flask Size	Quantity per Tractor	Mold Gang	Net Hourly Production	20,000 Units/Year Machine Operating Hours	20,000 Units/Year Machine Setup Hours	60,000 Units/Year Machine Operating Hours	60,000 Units/Year Machine Setup Hours	90,000 Units/Year Machine Operating Hours	90,000 Units/Year Machine Setup Hours
CROSS-LOOP MACHINE										
Group I Parts	44x36x15									
Cylinder Block		1	1	150	143	54	428	65	642	60
Transmission Case		1	1	150	143	54	428	65	642	60
Clutch Housing		1	1	150	143	54	428	65	642	60
Rear Axle Housing		2	2	300	143	54	428	65	642	60
Rockshaft Housing		1	2	300	72	36	214	40	321	60
Group II Parts	44x28x10									
Cylinder Head		1	2	300	72	36	214	65	321	60
Oil Pan		1	2	300	72	36	214	65	321	60
Exhaust Manifold		1	2	300	72	36	214	65	321	60
Intake Manifold		1	3	450	48	24	143	54	214	65
Wheel Weights		2	1	150	286	54	856	80	1,284	80
Front Axle Housing		1	1	150	143	54	428	65	642	60
Total Hours - Cross-Loop Machine					1,337	492	3,995	694	5,992	685
Molding Lines Required										
Actual Number Required					.60		1.53		2.17	
Whole Machines					1.00		2.00		2.00	
Molding Line Utilization					60%		77%		109%	
IN-LINE MACHINE										
Group III Parts	30x30x8									
Front Axle Pivot Bracket		1	2	300	72	18	214	32	321	30
Differential Housing		1	3	450	48	12	143	27	214	32
Hydraulic Pump Support		1	6	900	24	12	72	18	107	20
Draft Link Support		1	2	300	72	18	214	32	321	30
Gear Housing		1	6	900	24	12	72	18	107	20
Control Pedal		1	6	900	24	12	72	18	107	20
Control Pedal		1	6	900	24	12	72	18	107	20
Front Support		1	4	600	36	18	107	20	160	30
Brake Plate		2	4	600	72	18	214	20	321	30
Flywheel		1	4	600	36	18	107	20	160	30
Clutch Plate (Engine)		1	3	450	48	12	143	27	214	32
Clutch Plate (PTO)		1	3	450	48	12	143	27	214	32
Clutch Cover		1	3	450	48	12	143	27	214	32

TABLE A3-1 (concluded)

Part Name	Flask Size	Quantity per Tractor	Mold Gang	Net Hourly Production	20,000 Units/Year Machine Operating Hours	20,000 Units/Year Machine Setup Hours	60,000 Units/Year Machine Operating Hours	60,000 Units/Year Machine Setup Hours	90,000 Units/Year Machine Operating Hours	90,000 Units/Year Machine Setup Hours
Group III Parts (cont.)	30x30x8									
Bearing Cap Set		1	5	1,000	22	11	65	20	97	20
Water Manifold		1	5	1,000	22	11	65	20	97	20
Cam Gear		1	5	1,000	22	11	65	20	97	20
Oil Cooler Body		1	16	3,200	7	4	20	10	30	15
Water Pump Impeller		1	16	3,200	7	4	20	10	30	15
Water Pump Body		1	6	1,200	18	9	54	13	81	20
Gear A		1	5	1,000	22	11	65	20	97	20
Countershaft		1	6	1,200	18	9	54	13	81	20
Gear B		1	8	1,600	14	7	40	20	60	15
Gear C		1	12	2,400	9	5	27	14	40	20
Gear D		1	22	4,400	5	3	15	8	22	11
Gear E		1	12	2,400	9	5	27	14	40	20
Pinion A		1	22	4,400	5	3	15	8	22	11
Collar A		1	22	4,400	5	3	15	8	22	11
Pinion B		1	14	2,800	8	4	23	12	35	18
Pinion C		1	12	2,400	9	5	27	14	40	20
Collar B		1	22	4,400	5	3	15	8	22	11
Shifter A		1	8	1,600	14	7	40	20	60	15
Shifter B		1	8	1,600	14	7	40	20	60	15
Cam A		1	8	1,600	14	7	40	20	60	15
Shifter C		1	8	1,600	14	7	40	20	60	15
Shifter D		1	8	1,600	14	7	40	20	60	15
Cam B		1	8	1,600	14	7	40	20	60	15
PTO Bearing Quill		1	4	800	28	14	80	20	120	25
PTO Gear A		1	12	2,400	9	5	27	14	40	20
PTO Gear B		1	5	1,000	22	11	65	20	97	20
Final Drive Gear		1	5	1,000	22	11	65	20	97	20
Hub		1	8	1,600	14	7	40	20	60	15
Body		1	16	3,200	7	4	20	10	30	15
Bracket		1	16	3,200	7	4	20	10	30	15
Piston Cover		1	16	3,200	7	4	20	10	30	15
Subtotal Analyzed Parts					983	396	2,905	780	4,344	880
Parts Not Analyzed										
Group A	30x30x8	48	8	1,200	856	344	2,568	700	3,852	750
Group B	30x30x8	30	16	3,200	200	80	600	200	903	200
Total Hours - In-Line Machines					2,039	820	6,073	1,680	9,099	1,830
Molding Lines Required										
Actual Number Required					.93		2.52		3.48	
Whole Machines					1.00		3.00		4.00	
Molding Line Utilization					93%		84%		87%	

Note: Machine utilization is based on 3,072 hours per machine per year.
Requirements include 7% scrap allowance.

TABLE A3-2

MOLDING LINE LOAD REQUIREMENTS
ACTUAL MAKE-BUY MIX

Part Name	Flask Size	Quantity per Tractor	Mold Gang	Net Hourly Production	20,000 Units/Year Machine Operating Hours	20,000 Units/Year Machine Setup Hours	60,000 Units/Year Machine Operating Hours	60,000 Units/Year Machine Setup Hours	90,000 Units/Year Machine Operating Hours	90,000 Units/Year Machine Setup Hours
IN-LINE MACHINE										
Group III Parts (from Table A3-1)	30x30x8				983	396	2,905	780	4,344	880
Less: Parts Not Cast at 20,000:										
Flywheel		1	4	600	36	18				
Clutch Plate (Engine)		1	3	450	48	12				
Clutch Plate (PTO)		1	3	450	48	12				
Clutch Cover		1	3	450	48	12				
Bearing Cap Set		1	5	1,000	22	11				
Cam Gear		1	5	1,000	22	11				
Oil Cooler Body		1	16	3,200	7	4				
Water Pump Impeller		1	16	3,200	7	4				
Total Deletions					238	84				
Total Hours - Analyzed Parts					745	312	2,905	780	4,344	880
Parts Not Analyzed (Quantity)										
Group A	30x30x8		8	1,200	(36) 642	200	(48) 2,568	700	(62) 4,975	1,000
Group B	30x30x8		16	3,200	(24) 160	83	(30) 600	200	(41) 1,234	250
Total Hours - In-Line Machines					1,547	595	6,073	1,680	10,553	2,130
Molding Lines Required										
Actual Machines Required					.70		2.52		4.13	
Whole Machines					1.00		3.00		5.00	
Molding Line Utilization					70%		84%		82%	

Note: Machine utilization based on 3,072 hours per machine per year.
Requirements include 7% scrap allowance.

TABLE A4-1

IRON REQUIREMENTS

Part Name	Mold Gang	Weight Casting	Weight Gates (pounds)	Weight Total Mold	Production Rate, Molds per Hour: Maximum	Production Rate, Molds per Hour: Average	Iron Requirements, Tons per Hour: Maximum	Iron Requirements, Tons per Hour: Average	Maximum Iron Requirements With Critical Parts On Each Molding Line, Tons per Hour: 20,000 Units/Year	60,000 Units/Year	90,000 Units/Year Constant	90,000 Units/Year Variable
Group I Parts												
Cylinder Block	1	476	204	680	200	150	68	51				
Transmission Case	1	628	269	897	200	150	90	68	90	90	90	90
Clutch Housing	1	312	134	446	200	150	44	33				
Rear Axle Housing	2	205	171	586	200	150	58	44				
Rockshaft Housing	2	175	150	500	200	150	50	38				
Group II Parts												
Cylinder Head	2	160	137	457	240	150	55	34		55	55	55
Oil Pan	2	56	48	160	240	150	19	12				
Intake Manifold	3	43	55	184	240	150	22	14				
Exhaust Manifold	2	35	30	100	240	150	12	8				
Front Axle Pivot Bracket	2	80	69	229	240	150	28	17				
Group III Parts												
Front Axle Housing	1	100	43	143	240	150	17	11				
Flywheel	3	80	137	377	240	150	44	28		44	44	44
Differential Housing	3	50	64	214	240	150	26	16				
Brake Plate	4	40	69	229	240	150	28	17				
Front Plate Support	4	75	129	429	240	150	52	32	52	52	52	52
Hydraulic Pump Support	6	50	129	429	240	150	52	32		52	52	52
Wheel Weight	1	150	64	214	240	150	26	16				
Clutch Plates (3)	3	70	90	300	240	150	36	23				36
Water Manifold	5	10	21	71	300	200	11	7			32	32
Bearing Cap Set	5	30	64	214	300	200	32	21				
							Maximum Hourly Iron Requirement		142	293	325	361

Note: Total mold weight based on 70% mold yield, 25% gates and sprue, and 5% machine allowance.

TABLE A5-1
CORE REQUIREMENTS

Part Name	Core Name	Cores per Tractor	Cores per Box	Core Weights (pounds)	Total Core Weight per Tractor (pounds)
LARGE CORE MACHINE					
Cylinder Block	Barrel Core A	1	2	25	25
Cylinder Block	Barrel Core B	1	2	25	25
Cylinder Block	Barrel Core C	1	2	25	25
Cylinder Block	Barrel Core D	1	2	25	25
Cylinder Block	Barrel Core E	1	2	25	25
Cylinder Block	Barrel Core F	1	2	25	25
Cylinder Block	Water Jacket Core	1	2	16	16
Cylinder Block	End Core	1	2	25	25
Cylinder Head	Intake Port Core	1	2	4	4
Cylinder Head	Exhaust Port Core	1	2	6	6
Cylinder Head	Water Jacket Core	1	2	20	20
Cylinder Head	Side Core	1	2	20	20
Cylinder Head	Upper Core	1	2	10	10
Transmission Case	Body Core	1	1	75	75
Transmission Case	Body Core	1	2	35	35
Transmission Case	Side Core	1	2	10	10
Clutch Housing	Body Core	1	2	35	35
Clutch Housing	Side Core	1	2	10	10
Clutch Housing	End Core	1	2	15	15
Rear Axle Housing	Body Core A	2	2	25	50
Rear Axle Housing	Body Core B	2	1	25	50
Rockshaft Housing	Body Core	1	2	30	30
Rockshaft Housing	Side Core	1	2	10	10
Intake Manifold	Body Core	1	2	10	10
Exhaust Manifold	Body Core	1	2	12	12
Front Axle Pivot Bracket	Body Core	1	2	15	15
Front Axle	Body Core	1	2	30	30
Front Axle	End Core	2	2	5	10
Flywheel	Body Core	1	2	15	15
Differential Housing	Body Core	1	2	10	10
Front Support	Body Core	1	3	40	40
Hydraulic Pump Support	Body Core	1	3	5	5
Final Drive Gear Housing	Body Core	1	2	15	15
Clutch Cover	End Core	1	3	7	7
Water Manifold	Body Core	1	3	5	5

TABLE A5-1 (Concluded)

Part Name	Core Name	Cores per Tractor	Cores per Box	Core Weights (pounds)	Total Core Weight per Tractor (pounds)
SMALL CORE MACHINE					
Oil Cooler	Body Core	1	8	1	1
Water Pump	Body Core	1	2	2	2
Gear	Pin Core	6	10	1	6
Hub	Pin Core	2	10	1.5	3
Wheel Weight	Pin Core	2	10	1	2

TABLE A5-2

CORE MACHINE LOAD CALCULATIONS

Core Description	Quantity Cores per Tractor	Cores per Box	Net Hourly Production	CONSTANT MAKE-BUY MIX: 20,000 Units/Year: Machine Operating Hours	20,000 Units/Year: Machine Setup Hours	60,000 Units/Year: Machine Operating Hours	60,000 Units/Year: Machine Setup Hours	90,000 Units/Year: Machine Operating Hours	90,000 Units/Year: Machine Setup Hours
LARGE CORE MACHINE									
Miscellaneous Body Cores	4	3	180	520	156	1,560	390	2,340	470
Engine and Housing Cores	31	2	120	6,050	1,815	18,150	4,540	27,200	5,440
Transmission Case Core	2	1	60	780	234	2,340	585	3,510	700
Total Analyzed Parts				7,350	2,205	22,050	5,515	33,050	6,610
Total Parts Not Analyzed	25	2	120	4,875	1,463	14,625	3,660	21,950	4,390
Total Hours Large Core Machine Load				12,225	3,668	36,675	9,175	55,000	11,000
Number of Machines				6		15		22	
SMALL CORE MACHINE									
Pin Cores	10	10	600	390	120	1,170	295	1,755	350
Oil Cooler Body Core	1	8	480	50	15	150	40	220	45
Pump Body Core	1	2	120	195	60	585	145	880	175
Total Analyzed Parts				635	195	1,905	480	2,855	570
Total Parts Not Analyzed	40	8	480	1,950	585	5,850	1,470	8,775	1,755
Total Hours Small Core Machine Load				2,585	780	7,755	1,950	11,630	2,325
Number of Machines				1		4		5	
Bench Core Machines (Estimated)				2,000	600	4,000	800	5,000	1,000
Number of Machines				1		2		2	
Total Core Machine Load - Constant Make-Buy Mix				16,810	5,048	48,430	11,925	71,630	14,325
ACTUAL MAKE-BUY MIX									
Adjustment for Actual Make-Buy Mix (Based on Manufacturing Cost)				-1,180	-354	-	-	+9,310	+1,862
Total Core Machine Load - Actual Make-Buy Mix				15,630	4,694	48,430	11,925	80,940	16,187
Number of Large Core Machines				6		15		25	
Number of Small Core Machines				1		4		6	

Note: Requirements include 17% scrap allowance.

TABLE A6-1

FOUNDRY EQUIPMENT REQUIREMENTS

CONSTANT MAKE-BUY MIX

(U.S. Dollars)

Equipment Description	Cost per Machine (thousands)	20,000 Units/Year Machines Required	20,000 Units/Year Machinery Cost (thousands)	20,000 Units/Year Tooling Cost (thousands)	20,000 Units/Year Area (sq. ft.)	60,000 Units/Year Machines Required	60,000 Units/Year Machinery Cost (thousands)	60,000 Units/Year Tooling Cost (thousands)	60,000 Units/Year Area (sq. ft.)	90,000 Units/Year Machines Required	90,000 Units/Year Machinery Cost (thousands)	90,000 Units/Year Tooling Cost (thousands)	90,000 Units/Year Area (sq. ft.)
MELTING													
Melting Furnace	$500	2	$ 1,000			5	$ 2,500			7	$ 3,500		
Holding Furnace	750	1	750			4	3,000			6	4,500		
Charging Equipment	250	1	250			3	750			4	1,000		
Hot Melt Carrier System	125	1	125			2	250			3	375		
Pouring Equipment	125	2	250			4	500			5	625		
Remelt Conveyor	200	1	200			2	400			3	600		
Subtotal Melting		8	$ 2,575		75,000	20	$ 7,400		140,000	28	$10,600		200,000
MOLDING													
Cross-Loop Molding Line	800	1	$ 800	$ 400		2	$ 1,600	$ 400		2	$ 1,600	$ 400	
In-Line Molding Line	450	1	450	950		3	1,350	950		4	1,800	950	
Molding Conveyor	300	2	600			5	1,500			6	1,800		
Pattern Equipment				940				940				940	
Shake-out Equipment	150	2	300			5	750			6	900		
Molding Sand System	350	2	700			5	1,750			6	2,100		
Jobbing Floor Equipment			100				200				300		
Subtotal Molding		8	$ 2,950	$2,290	50,000	20	$ 7,150	$2,290	110,000	24	$ 8,500	$2,290	140,000
CORE-MAKING													
Large Core Machine	60	6	$ 360	$		15	$ 900	$		22	$ 1,320	$	
Small Core Machine	50	1	50			4	200			5	250		
Bench Core Machine	10	1	10			2	20			2	20		
Dip Drying Oven	50	1	50			2	100			3	150		
Core Sand System	300	1	300			4	1,200			6	1,800		
Core Assembly Fixtures	150	1	150	250		2	300	350		2	300	500	
Subtotal Core-Making		11	$ 920	$ 250	10,000	29	$ 2,720	$ 350	25,000	40	$ 3,840	$ 500	30,000
CLEANING													
Batch Type Blast	25	1	$ 25			1	$ 25			2	$ 50		
Cabinet Blast	200	1	200			2	400			3	600		
Continuous Blast	175	1	175			2	350			3	525		
Auto Grinder	50									1	50		
Stand Grinders	1	3	3			7	7			10	10		
Cooling Conveyors	400	2	800			4	1,600			5	2,000		
Process Conveyor	30	4	120			8	240			12	360		
Portable Grinders	1	6	6			24	24			36	36		
Subtotal Cleaning		18	$ 1,329		10,000	48	$ 2,646		48,000	72	$ 3,631		66,000
OTHER													
Exhaust-Emission Control and Ventilation System			$ 2,000				$ 4,500				$ 6,500		
Utility Services			200				250				400		
Electrical and Substation			600				800				1,200		
Annealing Furnace(s)	200	1	200		2,000	1	200		2,000	2	400		4,000
Compressed Air System			500				800				1,200		
Pattern Shop and Maintenance			150		20,000		200		30,000		300		40,000
Metallurgical Lab Equipment			20		2,000		40		4,000		60		6,000
Inspection Equipment			10		1,000		30		3,000		50		5,000
Materials Handling Equipment			50				130				200		
Subtotal Other		1	$ 3,730		25,000	1	$ 6,950		39,000	2	$10,310		55,000
Totals - Constant Make-Buy Mix		46	$11,504	$2,540	170,000	118	$26,866	$2,640	362,000	166	$36,881	$2,790	491,000

TABLE A6-2

FOUNDRY EQUIPMENT REQUIREMENTS

ACTUAL MAKE-BUY MIX

(U.S. Dollars)

Equipment Description	Cost per Machine (thousands)	20,000 Units/Year				60,000 Units/Year				90,000 Units/Year			
		Machines Required	Machinery Cost ---- (thousands)	Tooling Cost (thousands) ----	Area (sq. ft.)	Machines Required	Machinery Cost ---- (thousands)	Tooling Cost (thousands) ----	Area (sq. ft.)	Machines Required	Machinery Cost ---- (thousands)	Tooling Cost (thousands) ----	Area (sq. ft.)
Totals - Constant Make-Buy Mix		46	$11,504	$2,540	170,000	118	$26,866	$2,640	362,000	166	$36,881	$2,790	491,000
Adjustment for Actual Make-Buy Mix													
In-Line Molding Line	$450									1	450		20,000
Molding Conveyor	300									1	300		
Pattern Equipment				(120)								150	
Shakeout Equipment	150									1	150		
Molding Sand System	350									1	350		
Large Core Machine										3	180		
Small Core Machine										1	50		
Total Adjustment for Actual Make-Buy Mix		—	—	$ (120)	—	—	—	—	—	8	$ 1,480	$ 150	20,000
Total Actual Make-Buy Mix		46	$11,504	$2,420	170,000	118	$26,866	$2,640	362,000	174	$38,361	$2,940	521,000

TABLE A7-1

FOUNDRY MATERIALS COSTS
(U. S. Dollars)

			Cost per Gross Ton of Castings
Basic Material For Furnace Charge			
Material	Per Cent of Charge	Material Cost	
Pig Iron	33%	$66/Ton	$22
Returns and Remelt	33%	No Cost	
Scrap, Borings, and Turnings	33%	$40/Ton	13
Subtotal Basic Material			$35
Additives			$ 5
such as:			
Carbon			
Limestone			
Silicon			
Manganese			
Molding Materials			$15
such as:			
Molding Sand			
Core Sand			
Binders			
Total Material Cost			$55

TABLE A8-1

FOUNDRY FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
	(square feet)			(square feet)		
Space for Production Machinery (from Appendix 6)	147,000	325,000	440,000	147,000	325,000	460,000
Space for Pattern Shop and Maintenance Equipment (from Appendix 6)	20,000	30,000	40,000	20,000	30,000	40,000
Space for Inspection and Lab Operations (from Appendix 6)	3,000	7,000	11,000	3,000	7,000	11,000
Space for Access Aisles, Offices, and Miscellaneous (25% of total)	55,000	118,000	164,000	55,000	118,000	169,000
Total Space Requirements	225,000	480,000	655,000	225,000	480,000	680,000
Total Construction Cost @$35 per square foot (thousands of U.S. dollars)	$7,900	$16,800	$22,925	$7,900	$16,800	$23,800

TABLE A9-1
FOUNDRY INVENTORY COST CALCULATIONS
(U. S. Dollars)

Inventory Category	Scheduled Carrying Time in Weeks	Estimating Rate	Constant Make-Buy Mix			Actual Make-Buy Mix		
			20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
			(thousands)			(thousands)		
Raw Material	6	12 1/2% of material cost	$454	$1,361	$2,042	$440	$1,361	$2,083
In-Process	1	2% of variable cost	140	400	592	135	400	616
Complete	1	2% of variable and facility cost	208	532	767	201	532	798
Total Inventory Value			$802	$2,293	$3,401	$776	$2,293	$3,497
Annual Capital Cost of Inventory (7 1/2% of Value)			$ 60	$ 172	$ 255	$ 58	$ 172	$ 262

TABLE A10-1
BASIC PROCESS ROUTING
CROSS-LOOP MOLDING MACHINES

Operating Description and Equipment	Manpower
Mix Molding Sand	3
3 Mixers and Delivery System	
Set Drag Flask on Roll-In Table	Automatic
Make Drag Mold	1
Pneumatic Squeeze Machine, Sand Hopper, and Plows	
Roll Drag Mold Over and Set on Mold Conveyor	Automatic
Idle Station, Drag Roll Over, and Set on Unit	
Blow Mold Off and Spray if Necessary	Automatic
Set Chaplets as Required	2
Set Cores as Required	7
Core-Setting Fixture	
Set Cope Flask on Roll-In Table	Automatic
Make Cope Mold	1
Pneumatic Squeeze Machine, Sand Hopper, and Plows	
Inspect Cope Mold	1
Place Cope Mold on Drag	Automatic
Automatic Transfer and Closer	
Set Weights on Molds	Automatic
Check Pouring Temperature	1
Pour Iron into Molds	3
2000-Pound Ladle	
Break Sprue Cup	1
Remove Weights from Mold	Automatic
Strip Cope from Drag and Move Cope into Idle Station	Automatic
Cope Strip Unit and Idle Station	
Punch Out Sand and Set Flask on Roll-In Table	Automatic
Punch Out Station	
Pick Up and Push Drag Flask into Roll Over	Automatic
Pick off Station	
Roll Drag Mold Over - Casting Falls into Shaker	Automatic
Roll Over Unit	
Punch Out Sand from Drag	Automatic
Drag Punch Out Station	
Turn Drag Flask 180° and Set on Roll-In Table	Automatic
Raise and Rotator Unit	
Shake Out Castings	Automatic
Shaker Conveyor	
Load Castings to Cooling Conveyor	2
Dispose Gates and Sprues to Chute	1
Relief	2
Total Manpower	25

TABLE A10-2
BASIC PROCESS ROUTING
IN-LINE MOLDING MACHINES

Operation Description and Equipment	Manpower
Mix Molding Sand	2
2 Mixers and Delivery System	
Make Cope and Drag Molds	1
Dual Cope and Drag Mold Machine, Sand Hopper, Safety Guards, and Platforms	
Roll Drag Mold Over	Automatic
Drag Roll Over and Cope Cushion Machine	
Set Cores as Required	2
Core Conveyor	
Close Cope Mold on Drag Mold	Automatic
Mold Close Station	
Set Mold on Molding Conveyor	Automatic
Mold Pull on Station	
Set Weights on Molds	Automatic
Mold Weight Conveyor	
Check Pouring Temperature	1
Pour Iron into Mold	3
Remove Weights from Molds	Automatic
Push Mold off Mold Conveyor into Casting Punch Out Station	Automatic
Mold Push Off Station	
Punch Out Sand and Castings from Flask	Automatic
Sand and Casting Punch Out Machine	
Separate Cope Flask from Drag Flask	Automatic
Flask Separator Machine	
Remove Gates and Sprues	Automatic
Shaker Conveyor	
Load Castings to Cooling Conveyor	2
Relief	1
Total Manpower	12

TABLE A10-3
BASIC PROCESS ROUTING
CORE-MAKING

	Operation Description and Equipment
Groups I and II Parts	Mix Core Sand, Resin, and Catalyst and Deliver to Core Machine Core Sand Mixer and Delivery System
	Make Core and Place Core on Belt Hotbox or Shell Core Machine and Belt Conveyor
	Clean Core on Belt and Place on Core Rack or Clean Core and Place on Cure and Dip Conveyor
	Mix and Deliver Core Dip as Required
Group III Parts	Mix Core Sand, Resin, and Catalyst Core Sand Mixer and Delivery System
	Make Core and Deposit on Belt Hotbox and/or Shell Machine
	Clean Core on Belt and Load to Core Rack

TABLE A10-4
BASIC PROCESS ROUTING
CLEANING

	Operation Description and Equipment
Group I Parts	
	Unload Casting from Cooling Conveyor to Shaker Conveyor or Cushion Conveyor
	Shaker Conveyor, Cushion Conveyor, and Belt Conveyor
	Load Casting to Cabinet Shot Blast Conveyor
	Cabinet Blast
	Unload Casting to Shot Shake-Out Conveyor
	Chip Fins as Required
	Apron Conveyor
	* Load Automatic Grinder
	Chip Fins and Grind Burnt in Sand from Castings
	Apron Conveyor
	Inspect Casting
	Repair as Required
	Load Casting to Shipping Container
Group II Parts	
	Unload Castings from Cooling Conveyor Baskets to Shaker Conveyor
	(Automatic) Dump Station and Shaker Conveyor
	Load Castings into Continuous Type Blast
	(Automatic) Continuous Blast Cabinet
	Unload Castings from Blast onto Belt Conveyor
	(Automatic) Belt Conveyor
	Sort Castings
	Chip Fins from Casting as Required
	Grind Fins from Casting as Required
	Stand Grinder
	Repair Casting as Required
	Load Finished Casting to Shipping Container
Group III Parts	
	Unload Castings from Cooling Conveyor Baskets to Shaker Conveyor
	(Automatic) Dump Station and Shaker Conveyor
	Load Castings into Continuous Shot Blast
	(Automatic) Continuous Type Blast Machine
	Unload Castings from Blast onto Belt Conveyor
	(Automatic) Belt Conveyor
	Sort Out and Toss Castings Requiring Reblasting onto a Return Belt Conveyor
	Return Belt Conveyor
	Sort Castings into Hoppers above Grinders
	Belt Conveyor, Work Platform, and Casting Hoppers
	Chip or Grind Fins and Gates from Castings as Required
	Stand Grinders and Belt Conveyor
	Repair Castings as Required
	Load Finished Casting to Shipping Container

* For Cylinder Blocks

TABLE A11-1
FOUNDRY STAFFING CALCULATIONS

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
MOLDING ROOM						
DIRECT LABOUR						
1. Molding Man-Hours (from Appendix 3)						
Cross-Loop Machine @25 Men per Machine-Hour	33,425	99,875	149,800	33,425	99,875	149,200
Allowance for Pattern Changes - 25 Men @.5 Times Setup Hours	6,150	8,675	8,575	6,150	8,675	8,575
In-Line Machine @12 Men per Machine-Hour	24,468	72,876	109,188	18,564	72,876	126,636
Allowance for Pattern Changes - 12 Men @.5 Times Setup Hours	4,920	10,080	10,980	3,576	10,080	12,780
Total Molding Man-Hours	68,963	191,506	278,543	61,715	191,506	297,191
2. Number of Molding Line Workers (No. 1÷1,920 hours)	36	100	145	32	100	155
3. Setup Man-Hours (6 times machine setup hours in Appendix C)	7,872	14,244	15,090	6,522	14,244	16,890
4. Number of Setup Men (No. 3 ÷ 1,920 hours)	4	8	8	4	8	9
5. Total Molding Room Direct Labour (No. 2 + No. 4)	40	108	153	36	108	164
INDIRECT LABOUR						
6. Sort Remelt and Clean Up	8	24	36	8	24	40
7. Jobbing Floor	2	4	6	2	4	6
8. Utility, Flask, and Ladle Maintenance	4	12	18	4	12	20
9. Total Molding Room Indirect Labour (No. 6, 7, 8)	14	40	60	14	40	66
CORE ROOM						
DIRECT LABOUR						
10. Core Machine Man-Hours (from Appendix 5)	16,810	48,430	71,630	15,630	48,430	80,940
11. Number of Core Machine Operators (No. 1 ÷ 1,920 hours)	9	26	38	8	26	42
12. Setup Man-Hours (from Appendix 5)	5,048	11,925	14,325	4,694	11,925	16,187
13. Number of Setup Men (No. 3 ÷ 1,920 hours)	3	7	8	3	7	8
14. Core Cleaner (2 per operator)	18	52	76	16	52	84
15. Core Dipper (1 per operator)	9	26	38	8	26	42
16. Rack Filler (2 per operator)	18	52	76	16	52	84
17. Relief	4	10	16	3	10	18
18. Total Core Room Direct Labour (No. 11, 13 14 15, 16, 17)	61	173	252	54	173	278
INDIRECT LABOUR						
19. Mix and Deliver Sand	6	12	18	6	12	18
20. Mix and Deliver Core Dip	2	6	9	2	6	9
21. Jobbing Floor	4	8	12	4	8	12
22. Utility	4	12	18	4	12	18
23. Total Core Room Indirect Labour (No. 19, 20, 21, 22)	16	38	57	16	38	57

TABLE A11-2
FOUNDRY MANPOWER ALLOCATION
MELT SHOP

	Constant Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Direct Labour			
Charge Crane Operator	1	2	2
Weigh Master	1	2	2
Melting Furnace Operator	1	3	4
Melting Furnace Operator Helper	2	5	7
Utility Man	2	5	7
Holding Furnace Operator	1	4	6
Repair	4	9	13
Furnace Crane Operator	1	2	2
Direct Labour per Shift	13	32	43
Total Direct Labour (3 shifts)	39	96	129
Indirect Labour per Shift	4	6	8
Total Indirect Labour (3 shifts)	12	18	24

TABLE A11-3
FOUNDRY MANPOWER ALLOCATION
CLEANING ROOM AND INSPECTION

CLEANING ROOM	Constant Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Direct Labour Assigned to Equipment	(manpower)		
Batch Type Blast	1	1	2
Cabinet Blast	1	2	3
Continuous Blast	1	2	3
Auto Grinders	-	-	1
Stand Grinders - Double Wheel	3	7	10
Cooling Conveyors	-	-	-
Cooling Conveyors Unloading Station	2	4	5
Cushion Conveyors	1	1	1
Chipping Conveyors	12	48	72
Relief	1	2	3
Direct Labour per Shift	22	67	100
Total Direct Labour (2 shifts)	44	134	200
Indirect Labour per Shift	5	12	18
Total Indirect Labour (2 shifts)	10	24	36
INSPECTION			
Direct Labour Inspection per Shift	6	15	22
Total Direct Labour Inspection	12	30	44
Indirect Labour Inspection per Shift	1	1	2
Total Indirect Labour Inspection	2	4	6

TABLE A11-4
MANPOWER SUMMARY
FOUNDRY WORKERS AND INSPECTORS

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR - FOUNDRY WORKERS						
Melt Shop	39	96	129	38	96	132
Molding Room	40	108	153	36	108	164
Core Room	61	173	252	54	173	278
Cleaning Room	44	134	200	41	134	226
Total Direct Labour - Foundry Workers	184	511	734	169	511	800
Total Direct Labour - Inspectors	12	36	58	12	36	66
INDIRECT LABOUR - FOUNDRY WORKERS						
Melt Shop	12	18	24	12	18	24
Molding Room	14	40	60	14	40	66
Core Room	16	38	57	16	38	57
Cleaning Room	10	24	36	9	24	41
Total Indirect Labour - Foundry Workers	52	120	177	51	120	188
Total Indirect Labour - Inspectors	4	6	8	4	6	8

TABLE A11-5
DETAILED MANNING TABLE
FOUNDRY

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR						
Foundry Workers	184	511	734	169	511	800
Inspectors	12	36	58	12	36	66
Absentees and Trainees	22	61	88	20	61	96
Subtotal Direct Labour	218	608	880	201	608	962
INDIRECT LABOUR						
Foundry Workers	52	120	177	51	120	188
Inspectors	4	6	8	4	6	8
Materials Handlers	6	15	25	6	15	28
Pattern Makers	15	40	60	15	40	60
Machine Repair and Oilers	8	20	30	8	20	30
Crib Attendants	2	5	8	2	5	8
Sweepers	6	16	22	6	16	22
Subtotal Indirect Labour	93	222	330	92	222	344
SUPPORT STAFF						
Superintendent	1	1	1	1	1	1
Assistant Superintendent	-	2	4	-	2	4
General Foreman	4	8	11	4	8	12
Foreman	15	38	55	14	38	60
Clerical	5	11	13	5	11	13
Lab Technicians	4	6	9	4	6	9
Subtotal Support Staff	29	66	93	28	66	99
Total Staff - Foundry	340	896	1,303	321	896	1,405

TABLE A11-6

FOUNDRY PAYROLL COST CALCULATIONS
(Thousands of U.S. dollars)

	Rate	Constant Make-Buy Mix			Actual Make-Buy Mix		
		20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR							
Foundry Workers, Absentees, Trainees	$ 5.6	$1,153.6	$3,203.2	$4,603.2	$1,058.4	$3,203.2	$ 5,017.6
Inspectors	5.6	67.2	201.6	324.8	67.2	201.6	369.6
Total Direct Labour		$1,220.8	$3,404.8	$4,928.0	$1,125.6	$3,404.8	$ 5,387.2
INDIRECT LABOUR							
Foundry Workers	5.3	$ 275.6	$ 636.0	$ 938.1	$ 270.3	$ 636.0	$ 996.4
Materials Handlers	5.3	31.8	79.5	132.5	31.8	79.5	148.4
Pattern Makers and Maintenance	6.2	142.6	372.0	558.0	142.6	372.0	558.0
Crib Attendants	5.3	10.6	26.5	42.4	10.6	26.5	42.4
Sweepers	4.8	28.8	76.8	105.6	28.8	76.8	105.6
Inspectors	5.9	23.6	35.4	47.2	23.6	35.4	47.2
Total Indirect Labour		$ 513.0	$1,226.2	$1,823.8	$ 507.7	$1,226.2	$ 1,898.0
SUPPORT STAFF							
Superintendent	14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8
Assistant Superintendent	11.8	-	23.6	47.2	-	23.6	47.2
General Foreman	9.5	38.0	76.0	104.5	38.0	76.0	114.0
Foreman	7.4	111.0	281.2	407.0	103.6	281.2	444.0
Typists	3.9	3.9	11.7	11.7	3.9	11.7	11.7
Clerks	4.2	8.4	16.8	21.0	8.4	16.8	21.0
Expeditors	5.0	10.0	20.0	25.0	10.0	20.0	25.0
Lab Technicians	6.2	24.8	37.2	55.8	24.8	37.2	55.8
Total Support Staff		$ 210.9	$ 481.3	$ 687.0	$ 203.5	$ 481.3	$ 733.5
PAYROLL FRINGE BENEFITS							
Direct Labour	30%	$ 366.0	$1,021.4	$1,478.4	$ 337.7	$1,021.4	$ 1,616.2
Indirect Labour	30	154.0	368.0	547.0	152.3	368.0	569.0
Support Staff	30	63.1	144.4	206.0	61.0	144.4	220.0
Total Fringe Benefits		$ 583.1	$1,533.8	$2,231.4	$ 551.0	$1,533.8	$ 2,405.2
Total Payroll Costs		$2,527.8	$6,646.1	$9,670.2	$2,387.8	$6,646.1	$10,423.9

TABLE A12-1
ANNUAL FOUNDRY FACTORY EXPENSES
(Thousands of U. S. dollars)

		Constant Make-Buy Mix			Actual Make-Buy Mix		
		20, 000 Units/Year	60, 000 Units/Year	90, 000 Units/Year	20, 000 Units/Year	60, 000 Units/Year	90, 000 Units/Year
1.	Refractories and Electrodes @ $3/ton	$198.0	$ 594.0	$ 891.0	$192.0	$ 594.0	$ 909.0
2.	Perishable Tools, Hand Tools, and Gages @ $50/direct man	10.9	30.4	44.0	10.0	30.4	48.1
3.	Abrasive Supplies @ $1/ton	66.0	198.0	297.0	64.0	198.0	303.0
4.	Replacement Parts - Patterns and Fixtures @ 2% of total tooling	50.8	52.8	55.8	48.4	52.8	58.8
5.	Contract Repairs and Calibrations	10.0	20.0	25.0	10.0	20.0	25.0
6.	Miscellaneous Factory Supplies @ $75/direct man	16.4	45.6	66.0	15.0	45.6	72.1
7.	Miscellaneous Clerical Supplies @ $200/support man	5.8	13.2	18.6	5.6	13.2	19.8
8.	Rework and Repairs @ 3% of direct labour	38.0	104.5	153.6	34.4	104.5	168.7
9.	Utilities @ $6/ton	396.0	1, 188.0	1, 782.0	384.0	1, 188.0	1, 818.0
10.	Heat @ $.20/square foot	45.0	96.0	131.0	45.0	96.0	136.0
11.	Sundry Expenses	15.0	30.0	40.0	15.0	30.0	40.0
12.	Contingencies	22.1	62.3	90.0	20.6	62.3	91.5
	Total	$874.0	$2, 434.8	$3, 594.0	$844.0	$2, 434.8	$3, 690.0

TABLE A13-1
FOUNDRY PRO FORMA ANNUAL OPERATING COSTS
(Thousands of U.S. dollars)

	Constant Make-Buy Mix			Actual Make-Buy Mix		
	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
MATERIALS	$ 3,630	$10,890	$16,335	$ 3,520	$10,890	$16,665
LABOUR						
Direct	$ 1,221	$ 3,405	$ 4,928	$ 1,126	$ 3,405	$ 5,387
Indirect	513	1,226	1,824	508	1,226	1,898
Fringe Benefits @ 30%	520	1,389	2,025	490	1,389	2,185
Subtotal - Labour	$ 2,254	$ 6,020	$ 8,777	$ 2,124	$ 6,020	$ 9,470
OPERATING EXPENSE						
Factory Expense	$ 874	$ 2,435	$ 3,594	$ 844	$ 2,435	$ 3,690
Support Staff Salaries and Fringe Benefits	274	626	893	264	626	954
Subtotal - Operating Expense	$ 1,148	$ 3,061	$ 4,487	$ 1,108	$ 3,061	$ 4,644
FACILITY COSTS						
Depreciation						
Building @ 5%	$ 395	$ 840	$ 1,146	$ 395	$ 840	$ 1,190
Equipment @ 10%	1,150	2,687	3,688	1,150	2,687	3,836
Tooling Amortization @ 33%	840	870	920	800	870	970
Insurance and Taxes @ 5%	970	2,183	2,990	970	2,183	3,108
Subtotal - Facility Costs	$ 3,355	$ 6,580	$ 8,744	$ 3,315	$ 6,580	$ 9,104
CAPITAL COSTS						
Interest on Facilities Investment @ 7 1/2%	$ 1,164	$ 2,620	$ 3,588	$ 1,164	$ 2,620	$ 3,730
Interest on Inventories @ 7 1/2%	60	172	255	58	172	262
Subtotal - Capital Costs	$ 1,224	$ 2,792	$ 3,843	$ 1,222	$ 2,792	$ 3,992
Total Operating Costs	$11,611	$29,343	$42,186	$11,289	$29,343	$43,875
COST PER UNIT (Actual Dollars)	$ 581	$ 490	$ 469	$ 564	$ 490	$ 488

TABLE A14-1
STAMPING MATERIALS COSTS
(U. S. Dollars)

Total Weight of Analyzed Parts Including Process and Scrap Allowance	600 lbs.
Estimated Weight of Parts Not Analyzed	400 lbs.
Total Weight of Sheet Metal per Tractor	1,000 lbs.
Total Sheet Metal Material Cost per Tractor @$. 07 per Pound	$70

Calculation of Volume Effect

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Per Cent Change	+7%	+5%	Base	-3%	+6%	+5%	Base	+47%
Cost per Unit	$75	$73	$70	$68	$74	$73	$70	$103

TABLE A15-1
STAMPING EQUIPMENT REQUIREMENTS

CONSTANT MAKE-BUY MIX
(U.S. Dollars)

Machine Code	Equipment Description	Cost per Machine (thousands)	20,000 Units/Year Machines Required	20,000 Machinery Cost (thousands)	20,000 Tooling Cost (thousands)	20,000 Total Area (sq. ft.)	30,000 Units/Year Machines Required	30,000 Machinery Cost (thousands)	30,000 Tooling Cost (thousands)	30,000 Total Area (sq. ft.)	60,000 Units/Year Machines Required	60,000 Machinery Cost (thousands)	60,000 Tooling Cost (thousands)	60,000 Total Area (sq. ft.)	90,000 Units/Year Machines Required	90,000 Machinery Cost (thousands)	90,000 Tooling Cost (thousands)	90,000 Total Area (sq. ft.)
	Analyzed Parts																	
700	10-Foot Shear	$ 29	1	$ 29	$ -	400	2	$ 58	$ -	800	3	$ 87	$ -	1,200	3	$ 87	$ -	1,200
701	150-Ton OBI Press	50	1	50	26.4	200	1	50	26.4	200	2	100	26.4	400	2	100	26.4	400
703	300-Ton Press	100	3	300	116.4	3,600	3	300	116.4	3,600	5	500	116.4	6,000	7	700	165.0	8,400
704	110-Ton OBI Press	24	2	48	34.8	1,200	2	48	34.8	1,200	4	96	34.8	2,400	5	120	42.0	3,000
707	Spot Welder	25	1	25	68.8	600	1	25	68.8	600	1	25	68.8	600	1	25	68.8	600
708	60-Ton OBI Press	16	2	32	60.0	1,200	3	48	60.0	1,800	3	48	60.0	1,800	5	80	84.0	3,000
709	100-Ton Press	64	1	64	-	1,000	2	128	-	2,000	3	192	-	3,000	3	192	-	3,000
710	10-Foot Brake Press	16	1	16	8.1	800	1	16	8.1	800	2	32	8.1	1,600	2	32	8.1	800
711	110-Ton OBI Press	32	1	32	40.0	1,200	1	32	40.0	1,200	2	64	40.0	2,400	2	64	40.0	2,400
712	400-Amp Wire Welder	4	6	24	43.2	9,600	9	36	43.2	14,400	18	72	43.2	28,800	27	108	67.8	41,600
714	3-Column Drill	4	1	4	10.0	360	2	8	10.0	720	3	12	10.0	1,080	3	12	10.0	1,080
715	200-Ton Press	95	1	95	21.0	1,200	1	95	21.0	1,200	2	190	21.0	2,400	2	190	21.0	2,400
716	80 KVA Spot Welder	5	1	5	120.0	400	1	5	120.0	400	1	5	120.0	400	1	5	120.0	400
717	Assembly				1.8	440			1.8	430			1.8	520			1.8	670
718	Abrasive Cutoff	2	1	2	.2	400	1	2	.2	400	1	2	.2	400	1	2	.0	400
719	Rolling Machine	17	1	17	3.6	1,600	1	17	3.6	1,600	1	17	3.6	1,600	1	17	3.6	1,600
720	60-Ton Press	16	1	16	75.0	800	1	16	75.0	800	1	16	75.0	800	1	16	75.0	800
721	Drill Press	2	1	2	.6	450	2	4	.6	900	3	6	.6	1,350	4	8	.6	1,800
722	Surface Grinder	25	1	25	-	600	1	25	-	600	1	25	-	600	2	50	-	1,200
724	150-Ton Press	75	2	150	340.0	2,400	2	150	340.0	2,400	3	225	340.0	3,600	4	300	340.0	4,800
726	Lock Form Machine	12	1	12	3.0	450	1	12	3.0	450	1	12	3.0	450	1	12	3.0	450
728	Riveting Machine	5	1	5	.5	300	1	5	.5	300	1	5	.5	300	2	10	.5	600
729	Barrel Tumbler	3	1	3	-	600	1	3	-	600	1	3	-	600	1	3	-	600
730	Drill Press	4	1	4	-	400	1	4	-	400	1	4	-	400	1	4	-	400
	Subtotal - Fabricating Equipment		33	$ 960	$ 973.4	30,000	41	$1,087	$ 973.4	37,800	63	$1,738	$ 973.4	62,700	81	$2,137	$1,077.8	81,600
705	Washer	35	1	35	4.5	900	2	70	4.5	1,800	4	140	4.5	3,600	6	210	6.0	5,400
706	Paint System	225	1	225	9.1	20,400	1	2,225	9.1	20,400	2	450	9.1	40,800	2	450	10.2	40,800
	Total Analyzed Parts		35	$1,220	$ 987.0	51,500	44	$1,382	$ 987.0	60,000	70	$2,328	$ 987.0	107,100	89	$2,797	$1,094.0	127,800
Equipment for Parts Not Analyzed (see Table A15-3)			2	53	276.0	1,800	3	61	276.0	2,700	20	500	276.0	18,000	24	591	276.0	21,600
Inspection Equipment				10		1,000		10		1,200		10		2,400		10		2,500
Materials Handling Equipment				60		-		60		-		115		-		175		-
Die Room, Maintenance, and Miscellaneous			—	106	—	20,000	—	127	—	20,000	—	200	—	30,000	—	273	—	30,000
Total			37	$1,449	$1,263.0	74,300	47	$1,640	$1,263.0	83,900	90	$3,153	$1,263.0	157,500	113	$3,846	$1,370.0	181,900

TABLE A15-2

STAMPING EQUIPMENT REQUIREMENTS

ACTUAL MAKE-BUY MIX
(U.S. Dollars)

Equipment Description	20,000 Units/Year				30,000 Units/Year				60,000 Units/Year				90,000 Units/Year			
	Machines Required	Machinery Cost	Tooling Cost	Total Area	Machines Required	Machinery Cost	Tooling Cost	Total Area	Machines Required	Machinery Cost	Tooling Cost	Total Area	Machines Required	Machinery Cost	Tooling Cost	Total Area
		-----(thousands)-----		(sq. ft.)		-----(thousands)-----		(sq. ft.)		-----(thousands)-----		(sq. ft.)		-----(thousands)-----		(sq. ft.)
Equipment for Analyzed Parts (from Table A15-1)	35	$1,220	$ 990	51,500	44	$1,382	$ 990	60,000	70	$2,328	$ 990	107,500	89	$2,797	$1,094	127,800
Equipment for Parts Not Analyzed (see Table A15-3)	2	40	248	1,800	3	61	276	2,700	20	500	276	18,000	94	2,352	360	84,600
Inspection Equipment		10		1,000		10		1,200		10		2,000		12		3,000
Materials Handling Equipment		50				60				115				200		
Die Room, Maintenance, and Miscellaneous	—	106	—	20,000	—	127	—	20,000	—	200	—	30,000	—	273	—	30,000
Total	37	$1,426	$1,238	74,300	47	$1,640	$1,266	83,900	90	$3,153	$1,266	157,500	183	$5,634	$1,454	245,400

TABLE A15-3
CALCULATION OF STAMPING EQUIPMENT FOR COMPONENTS NOT ANALYZED
(U.S. Dollars)

Calculation Steps	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90.000 Units/Year
1. Total Value of "Make" Parts (manufacturer's cost from Appendix 2)	$ 262	$ 262	$ 262	$ 262	$ 260	$ 262	$ 262	$ 397
2. Value of Parts Analyzed (from Appendix 1)	$ 182	$ 182	$ 182	$ 182	$ 182	$ 182	$ 182	$ 182
3. Per Cent of Parts Analyzed (No. 2 ÷ No. 1) (100)	69%	69%	69%	69%	70%	69%	69%	47%
4. Cost of Equipment Required by Parts Analyzed (from Table A15-1)	$ 1,220	$ 1,382	$ 2,328	$ 2,797	$ 1,220	$ 1,382	$ 2,328	$ 2,797
5. Scheduled Machine Utilization for Analyzed Parts*	72.4%	72.4%	84.2%	84.0%	72.4%	72.4%	84.2%	84.0%
6. Value of Output at 100% Utilization (No. 2 ÷ No. 5) (100)	$ 251	$ 251	$ 216	$ 217	$ 251	$ 251	$ 216	$ 217
7. Per Cent of Equipment Requirements Specified (No. 6 ÷ No. 1) (100)	95.8%	95.8%	82.4%	82.6%	96.8%	95.8%	82.4%	54.4%
8. Value of Additional Equipment Required (100 - No. 7) (No. 4 ÷ No. 7)	$ 53,000	$ 61,000	$500,000	$591,000	$ 40,000	$ 61,000	$500,000	$2,352.000
9. Number of Additional Machines (No. 8 ÷ $25,000)	2	3	20	24	2	3	20	94
10. Additional Floor Space Required (No. 9 x 900 sq. ft./machine)	1,800	2,700	18,000	21,600	1,800	2,700	18,000	84.600
11. Estimated Additional Tool Costs (number of additional parts x $2,000)	$276,000	$276,000	$276,000	$276,000	$248,000	$276,000	$276,000	$ 360.000

* Based on machine hours required vs. 3,072 hours per machine (80% of planned operation)

TABLE A16-1
STAMPING FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
	(square feet)				(square feet)			
Space for Production Machinery (from Appendix 15)	53,300	62,700	125,500	149,400	53,300	62,700	125,500	212,400
Space for Die Room and Maintenance Equipment (from Appendix 15)	20,000	20,000	30,000	30,000	20,000	20,000	30,000	30,000
Space for Inspection Operations (from Appendix 15)	1,000	1,200	2,000	2,500	1,000	1,200	2,000	3,000
Space for Access Aisles, Offices, and Miscellaneous (25% of total)	25,700	28,500	52,500	61,100	25,700	28,500	52,500	82,100
Total Space Requirements	100,000	112,400	210,000	243,000	100,000	112,400	210,000	327,500
Total Construction Cost @$10.50 per square foot (thousands of U.S. dollars)	$1,050	$1,180	$2,205	$2,552	$1,050	$1,180	$2,205	$3,439

TABLE A17-1
STAMPING INVENTORY COST CALCULATIONS
(U.S. Dollars)

Inventory Category	Scheduled Carrying Time in Weeks	Estimating Rate	Constant Make-Buy Mix				Actual Make-Buy Mix			
			20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
			(thousands)				(thousands)			
Raw Material	6	12 1/2% of material cost	$188	$271	$525	$ 764	$186	$271	$525	$1,159
In-Process	1	2% of variable cost	53	74	136	196	52	74	136	290
Finished	1	2% of variable and facility costs	67	90	159	221	66	90	159	323
Total Inventory Value			$308	$435	$820	$1,181	$304	$435	$820	$1,772
Annual Capital Cost of Inventory (7 1/2% of Value)			$ 23	$ 33	$ 62	$ 89	$ 23	$ 33	$ 62	$ 133

TABLE A18-1
STAMPING LABOUR REQUIREMENTS

CONSTANT MAKE-BUY MIX

Machine Code	Equipment Description	20,000 Units/Year		30,000 Units/Year		60,000 Units/Year		90,000 Units/Year	
		Operating Man-Hours	Setup Hours	Operating Man-Hours	Setup Hours	Operating Man-Hours	Setup Hours	Operating Man-Hours	Setup Hours
700	10-Foot Shear	2,663	1,772	3,994	1,772	7,988	2,861	11,981	2,861
701	150-Ton OBI Press	1,004	860	1,476	860	2,952	1,290	4,428	1,590
703	300-Ton Press	6,552	5,000	8,340	5,000	16,680	7,500	25,250	7,500
704	110-Ton OBI Press	3,332	3,550	4,998	3,550	9,996	5,325	14,994	5,325
707	Spot Welder	924	150	1,386	150	2,772	225	4,158	225
708	60-Ton OBI Press	2,141	4,900	3,212	4,900	6,428	5,350	9,639	5,350
709	100-Ton Press	1,848	1,850	2,772	1,850	5,544	2,775	8,346	2,775
710	10-Foot Brake Press	1,276	1,323	1,914	1,323	3,384	1,763	5,176	1,763
711	110-Ton OBI Press	888	650	1,332	650	2,664	975	3,996	975
712	400-Amp Wire Welder	20,760	700	31,140	700	62,280	1,050	94,420	1,050
713	Grinders	9,532	-	12,798	-	25,596	-	38,394	-
714	3-Column Drill	1,872	450	2,808	450	5,616	675	8,424	675
715	200-Ton Press	730	1,100	1,095	1,100	2,190	1,650	3,285	1,650
716	80 KVA Spotwelder	1,010	150	1,515	150	3,030	225	4,545	225
717	Assembly	260	50	390	50	780	75	1,170	75
718	Abrasive Cutoff	18	100	27	100	54	150	81	150
719	Rolling Machine	134	250	201	250	402	375	603	375
720	60-Ton Press	564	900	846	900	1,692	1,350	2,538	1,350
721	Drill Press	2,436	100	3,698	100	6,396	150	9,594	150
722	Surface Grinder	860	-	1,290	-	2,580	-	3,870	-
724	150-Ton Press	2,402	2,550	3,603	2,550	7,206	3,925	10,799	3,925
725	Post Grinder	680	-	1,020	-	2,040	-	3,060	-
726	Lock Form Machine	40	300	60	300	120	450	180	450
728	Riveting Machine	960	100	1,440	100	2,880	150	4,320	150
729	Barrel Tumbler	52	-	78	-	156	-	234	-
739	Drill Press	260	200	390	200	780	300	1,170	300
	Subtotal Fabricating Equipment	63,198	27,005	91,823	27,005	182,206	38,589	274,655	38,889
705	Washer	5,894	-	8,290	-	16,582	-	24,813	-
706	Paint System	11,836	-	17,739	-	35,478	-	53,217	-
	Total Analyzed Parts	80,928	27,005	117,852	27,005	234,266	38,589	352,685	38,889
	Fabricating Time for Parts Not Analyzed*	36,372	27,600	52,948	27,600	105,234	27,600	158,415	27,600
	Grand Total	117,300	54,605	170,800	54,605	339,500	66,189	511,100	66,489
	Inspection								
	Analyzed Parts	2,400		3,600		7,100		10,700	
	Parts Not Analyzed	1,080		1,600		3,200		4,800	
	Total Inspection	3,480		5,200		10,300		15,500	

* Analyzed parts represented 69% of fabricated components. Man-hours were increased in direct proportion. Setup hours were increased according to number of parts.

TABLE A18-2
STAMPING LABOUR REQUIREMENTS

ACTUAL MAKE-BUY MIX

Equipment Description	20,000 Units/Year		30,000 Units/Year		60,000 Units/Year		90,000 Units/Year	
	Operating Man-Hours	Setup Hours	Operating Man-Hours	Setup Hours	Operating Man-Hours	Setup Hours	Operating Man-Hours	Setup Hours
Fabricating Time for Analyzed Parts (from Table A18-1)	80,928	27,005	117,852	27,005	234,266	38,589	352,685	38,889
Fabricating Time for Parts Not Analyzed*	34,672	24,800	52,948	27,600	105,234	27,600	397,715	36,000
Total	115,600	51,805	170,800	54,605	339,500	66,189	750,400	74,889
Inspection								
Analyzed Parts (from Table A18-1)	2,400		3,600		7,100		10,700	
Parts Not Analyzed	1,030		1,600		3,200		12,100	
Total - Inspection	3,430		5,200		10,300		22,800	

* Analyzed parts comprise the following per cent of fabricated components: 20,000 - 70%, 30,000 - 69%, 60,000 - 69%, 90,000 - 47%. Man-hours for parts not analyzed were increased in direct proportion.

TABLE A18-3

STAMPING DIRECT LABOUR CALCULATIONS AND DETAILED MANNING TABLE

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR								
1. Machine Operating Man-Hours*	117,300	170,800	339,500	511,100	115,600	170,800	339,500	750.400
2. Number of Machine Operators (No. 1 ÷ 1,920 hours)	61	89	177	266	60	89	177	391
3. Setup Man-Hours*	54,605	54,605	66,189	66,489	51,805	54,605	66,189	74.889
4. Number of Setup Men (No. 3 ÷ 1,920 hours)	28	28	35	35	27	28	35	39
5. Inspection Man-Hours*	3,480	5,200	10,300	15,500	3,430	5,200	10,300	22,800
6. Number of Inspectors (No. 5 ÷ 1,920 hours)	2	3	6	8	2	3	6	12
7. Absentee and Trainee Replacements (7 1/2% of total direct employees)	7	10	18	25	7	10	18	36
8. Total Direct Employees (No. 2 + 4 + 6 + 7)	98	130	236	334	96	130	236	478
9. Other Employees (estimated):								
INDIRECT LABOUR								
Materials Handlers								
In-Plant	2	4	6	8	2	4	6	10
Receiving and Shipping	1	1	2	3	1	1	2	4
Crane Operators	1	1	2	2	1	1	2	2
Inspectors								
Receiving	1	1	2	3	1	1	2	3
Layout	3	4	6	7	3	4	6	8
Plant Maintenance								
Tool and Die Makers	5	7	10	13	4	7	10	21
Machine Repair and Oilers	4	4	6	7	3	4	6	12
Crib Attendants	2	2	2	2	2	2	2	3
Sweepers	1	2	2	4	1	2	2	6
Total Indirect Labour	20	26	38	49	18	26	38	69
SUPPORT STAFF								
Supervision								
Superintendent	1	1	1	1	1	1	1	1
Assistant Superintendent	-	-	1	2	-	-	1	2
General Foreman	1	2	3	3	1	2	3	4
Foreman	4	5	10	15	4	5	10	21
Clerical								
Typists	1	1	2	3	1	1	2	3
Plant Clerks	4	6	7	9	4	6	7	10
Expeditors	2	2	3	4	2	2	3	5
Total Support Staff	13	17	27	37	13	17	27	46
Total Staff - Stamping	131	173	301	420	127	173	301	593

* Data taken from Tables A18-1 and A18-2.

TABLE A18-4
STAMPING PAYROLL COST CALCULATIONS
(Thousands of U. S. dollars)

	Rate	Constant Make-Buy Mix 20,000 Units/Year	Constant Make-Buy Mix 30,000 Units/Year	Constant Make-Buy Mix 60,000 Units/Year	Constant Make-Buy Mix 90,000 Units/Year	Actual Make-Buy Mix 20,000 Units/Year	Actual Make-Buy Mix 30,000 Units/Year	Actual Make-Buy Mix 60,000 Units/Year	Actual Make-Buy Mix 90,000 Units/Year
DIRECT LABOUR									
Operators, Absentees, and Trainees	$ 5.6	$380.8	$ 554.4	$1,092.0	$1,629.6	$375.2	$ 554.4	$1,092.0	$2,391.2
Setup Men	5.9	165.2	165.2	206.5	206.5	159.3	165.2	206.5	230.1
Inspectors	5.6	11.2	16.8	33.6	44.8	11.2	16.8	33.6	67.2
Total Direct Labour		$557.2	$ 736.4	$1,332.1	$1,880.9	$545.7	$ 736.4	$1,332.1	$2,688.5
INDIRECT LABOUR									
Materials Handlers	5.3	$ 21.2	$ 31.8	$ 53.0	$ 68.9	$ 21.2	$ 31.8	$ 53.0	$ 84.8
Die Makers and Maintenance	6.2	43.4	68.2	99.2	124.0	43.4	68.2	99.2	204.6
Crib Attendants	5.3	10.6	10.6	10.6	10.6	10.6	10.6	10.6	15.9
Sweepers	4.8	4.8	9.6	9.6	19.2	4.8	9.6	9.6	28.8
Inspectors	5.9	23.6	29.5	47.2	59.0	23.6	29.5	47.2	64.9
Total Indirect Labour		$103.6	$ 149.7	$ 219.6	$ 281.7	$103.6	$ 149.7	$ 219.6	$ 399.0
SUPPORT STAFF									
Superintendent	14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8
Assistant Superintendent	11.8	-	-	11.8	23.6	-	-	11.8	23.6
General Foreman	9.5	9.5	19.0	28.5	28.5	9.5	19.0	28.5	38.0
Foreman	7.4	29.6	47.5	74.0	142.5	29.6	47.5	74.0	199.5
Typists	3.9	3.9	3.9	7.8	11.7	3.9	3.9	7.8	11.7
Clerks	4.2	16.8	25.2	29.4	37.8	16.8	25.2	29.4	42.0
Expeditors	5.0	10.0	10.0	15.0	20.0	10.0	10.0	15.0	25.0
Total Support Staff		$ 84.6	$ 120.4	$ 181.3	$ 278.9	$ 84.6	$ 120.4	$ 181.3	$ 354.6
PAYROLL FRINGE BENEFITS									
Direct Labour	30%	$167.2	$ 220.9	$ 399.6	$ 564.3	$163.7	$ 220.9	$ 399.6	$ 806.6
Indirect Labour	30	31.0	44.9	65.9	84.5	31.0	44.9	65.9	119.7
Support Staff	30	25.4	36.1	54.4	83.7	25.4	36.1	54.4	106.4
Total Fringe Benefits		$223.6	$ 301.9	$ 519.9	$ 732.5	$220.1	$ 301.9	$ 519.9	$1,032.7
Total Payroll Costs		$969.0	$1,308.4	$2,252.9	$3,174.0	$954.0	$1,308.4	$2,252.9	$4,474.8

TABLE A19-1
ANNUAL STAMPING FACTORY EXPENSES
(Thousands of U. S. dollars)

		Constant Make-Buy Mix				Actual Make-Buy Mix			
		20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
1.	Lubricants and Compounds	$ 10.0	$ 15.0	$ 24.0	$ 45.0	$ 9.0	$ 15.0	$ 24.0	$ 60.0
2.	Perishable Tools, Welding and Abrasive Supplies, Hand Tools, and Gages @ $.25/machine-hour	30.0	35.0	70.0	90.0	30.0	35.0	70.0	145.0
3.	Replacement Parts - Dies and Fixtures	34.0	40.0	50.0	55.0	30.0	40.0	50.0	85.0
4.	Contract Repairs and Calibrations	8.0	12.0	20.0	40.0	8.0	12.0	20.0	60.0
5.	Miscellaneous Factory Supplies @ $75/direct man	6.0	8.0	15.0	22.0	6.0	8.0	15.0	32.0
6.	Miscellaneous Clerical Supplies @ $200/support man	2.6	3.4	5.4	7.4	2.6	3.4	5.4	9.2
7.	Rework and Repairs @ .2% of "make" cost	19.0	29.0	57.0	86.0	19.0	29.0	57.0	130.0
8.	Utilities @ $.15/machine-hour	17.5	22.0	41.5	55 0	17.5	22.0	41.5	87.0
9.	Heat @ $.20/square foot	20.0	22.5	42.0	49.0	20.0	22.5	42.0	65.5
10.	Sundry Expenses	5.0	7.5	15.0	20.0	5.0	7.5	15.0	25.0
11.	Contingencies	7.9	10.6	18.1	24.6	7.9	10.6	18.1	36.8
	Total	$160.0	$205.0	$358.0	$494.0	$155.0	$205.0	$358.0	$735.5

TABLE A20-1
STAMPING PRO FORMA ANNUAL OPERATING COSTS
(Thousands of U.S. dollars)

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
MATERIALS	$1,500	$2,190	$4,200	$ 6,111	$1,485	$2,190	$4,200	$ 9,270
LABOUR								
Direct	$ 557	$ 736	$1,332	$ 1,881	$ 546	$ 736	$1,332	$ 2,689
Indirect	104	150	220	282	104	150	220	399
Fringe Benefits @ 30%	198	266	466	649	195	266	466	926
Subtotal - Labour	$ 859	$1,152	$2,018	$ 2,812	$ 845	$1,152	$2,018	$ 4,014
OPERATING EXPENSE								
Factory Expense	$ 160	$ 205	$ 358	$ 494	$ 155	$ 205	$ 358	$ 736
Support Staff Salaries and Fringe Benefits	110	157	236	363	110	157	236	461
Subtotal - Operating Expense	$ 270	$ 362	$ 594	$ 857	$ 265	$ 362	$ 594	$ 1,197
FACILITY COSTS								
Depreciation								
Building @ 5%	$ 53	$ 59	$ 110	$ 128	$ 53	$ 59	$ 110	$ 172
Equipment @ 10%	145	164	315	385	143	164	315	563
Tooling Amortization @ 33%	418	418	418	452	409	418	418	480
Taxes and Insurance @ 5%	125	141	268	320	124	141	268	454
Subtotal - Facility Costs	$ 741	$ 782	$1,111	$ 1,285	$ 729	$ 782	$1,111	$ 1,669
CAPITAL COSTS								
Interest on Facilities Investment @ 7 1/2%	$ 150	$ 169	$ 321	$ 384	$ 149	$ 169	$ 321	$ 544
Interest on Inventories @ 7 1/2%	23	33	62	89	23	33	62	133
Subtotal - Capital Costs	$ 173	$ 202	$ 383	$ 473	$ 172	$ 202	$ 383	$ 677
Total Operating Costs	$3,543	$4,688	$8,306	$11,538	$3,496	$4,688	$8,306	$16,827
COST PER UNIT (Actual Dollars)	$ 177	$ 156	$ 138	$ 128	$ 175	$ 156	$ 138	$ 187

FIGURE A21-1
SCHEMATIC DIAGRAM OF
CYLINDER BLOCK MACHINING LINE

Operation	
Code Number	Description
10	Inspect casting Qualify casting for machining
20	Broach bottom surfaces Index Broach side surface Mill top surface
30	Drill and ream hole Index Mill front bearing bulkheads Index Mill rear bearing bulkheads Roll over and remove chips
40	Rough bore cylinders Index Chamfer top and bottom of bore
50	Index block Rough mill front and rear ends Mill pads - front end Mill left and right side

Stations Required

20,000 and 30,000 Units/Year	60,000 Units/Year	90,000 Units/Year

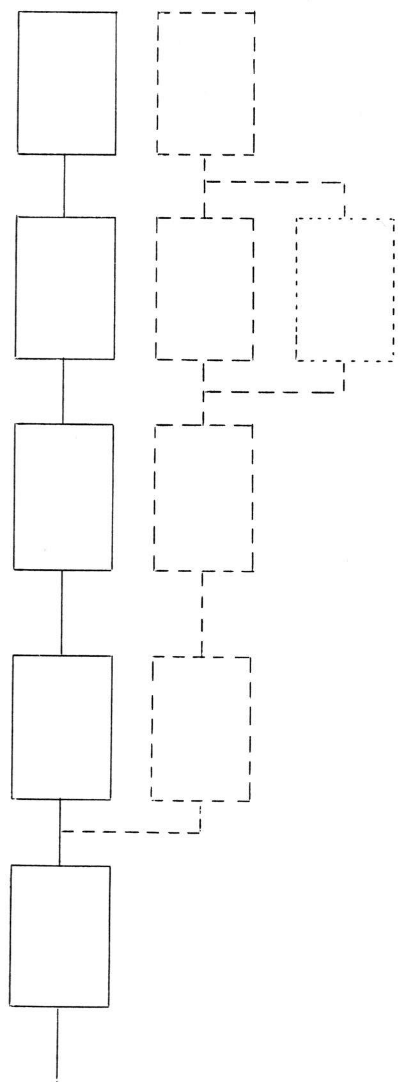


FIGURE A21-1 (Continued)

Operation		Stations Required		
Code Number	Description	20,000 and 30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
60	Drill holes - front and rear Ream holes - front and rear			
70	Tap holes - front and rear Tap nut - rear Probe inspect			
80	Gun drill oil gallery from front and rear			
90	Gun drill oil gallery Ream holes			
100	Drill holes for head Tap holes Drill with counterbore Drill and spotface Tap holes Probe inspect			

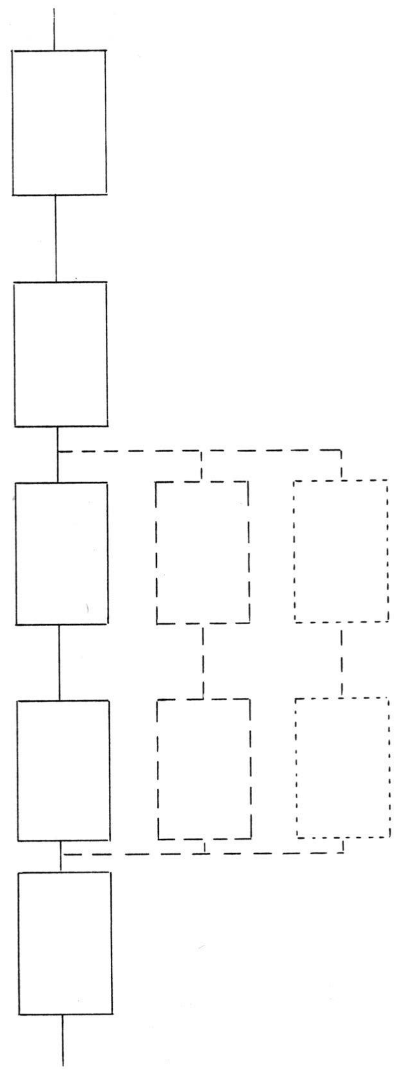


FIGURE A21-1 (Continued)

Operation		Stations Required		
Code Number	Description	20,000 and 30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
110	Semifinish and finish bore cylinders Counterbore Groove for O-rings			
120	Drill holes			
130	Tap holes Probe inspect			
140	Assemble bearing caps			
150	Mill cam bores Mill front and rear main bearing bores Insert bearing supports Mill inner main bearing bores			

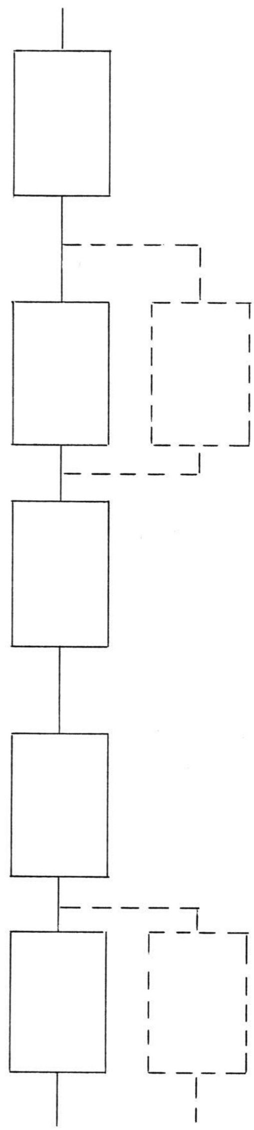


FIGURE A21-1 (Continued)

Operation		Stations Required		
Code Number	Description	20,000 and 30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
160	Insert camshaft bearings			
170	Deburr and clean			
180	Assemble cylinder liners			
190	Semifinish bore cylinder liners Reverse speed and finish bore			
200	Rough hone cylinder liners			

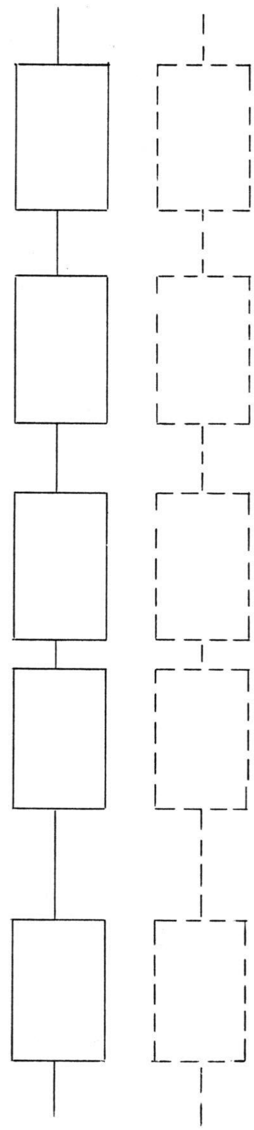


FIGURE A21-1 (Concluded)

Operation		Stations Required		
Code Number	Description	20,000 and 30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
210	Finish hone cylinder liners			
220	Line hone main bearings and cam bearings			
230	Wash			
240	Insert freeze plugs			
250	Leak test and blow out			

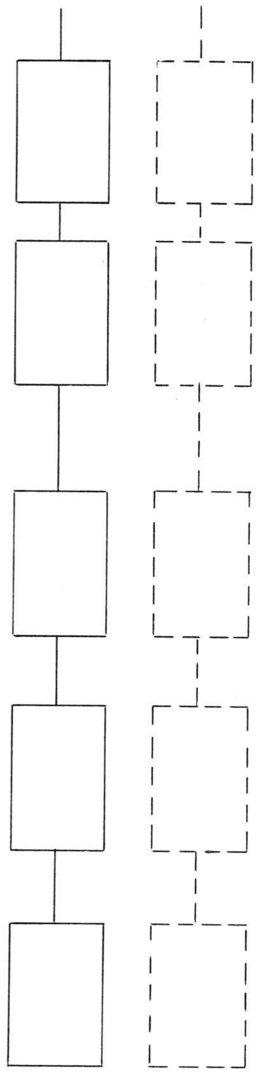


TABLE A22-1
MACHINING MATERIALS COSTS
(U. S. Dollars)

DETERMINATION OF ESTIMATING RATES

(1) Forgings

Part	Manufacturer's Cost	Estimated Weight	Estimated Materials Cost per Pound	Materials Cost	Materials Cost as a Per Cent of Total Cost
Crankshaft	$59	160	$. 20	$32	54%
Connecting Rod (6)	31	60	. 20	12	39

Forging Materials Cost - Use 40% of Manufacturer's Cost

(2) Aluminum

Part	Manufacturer's Cost	Estimated Weight	Estimated Materials Cost per Pound	Materials Cost	Materials Cost as a Per Cent of Total Cost
Piston (6)	$16	30	$. 25	$7. 50	47%

Aluminum Materials Cost - Use 45% of Manufacturer's Cost

(3) Bar Stock

Bar Stock Materials Cost - Use 10% of Manufacturer's Cost

(4) Tubing

Tubing Materials Cost - Use 15% of Manufacturer's Cost

CALCULATION OF MATERIALS COSTS

Material	Value of Machined Components	Estimated Per Cent of Cost for Materials	Materials Cost per Unit
Forgings	$261	40%	$105
Aluminum	21	45	8
Bar Stock	122	10	12
Tubing	134	15	20
		Total	$145

CALCULATION OF VOLUME EFFECT

Volume	20, 000 Units/Year	30, 000 Units/Year	60, 000 Units/Year	90, 000 Units/Year
Per Cent Change	+7%	+5%	Base	-3%
Materials Cost per Tractor	$155	$152	$145	$141

TABLE A22-2

MACHINING MATERIALS COSTS PER UNIT RELATED TO PRODUCTION VOLUME

(U.S. Dollars)

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Forgings	$ 112	$ 110	$ 105	$ 102	$ 82	$ 110	$ 105	$ 141
Aluminum	9	8	8	8	6	8	8	11
Bar Stock	13	13	12	12	9	13	12	16
Tubing	21	21	20	19	15	21	20	26
Total	$ 155	$ 152	$ 145	$ 141	$ 112	$ 152	$ 145	$ 194

TABLE A23-1
MACHINING EQUIPMENT REQUIREMENTS

CONSTANT MAKE-BUY MIX
(U.S. Dollars)

Machine Code	Equipment Description	Cost per Machine (thousands)	20,000 Units/Year Machines Required	20,000 Machinery Cost (thousands)	20,000 Tooling Cost (thousands)	20,000 Total Area (sq. ft.)	30,000 Units/Year Machines Required	30,000 Machinery Cost (thousands)	30,000 Tooling Cost (thousands)	30,000 Total Area (sq. ft.)	60,000 Units/Year Machines Required	60,000 Machinery Cost (thousands)	60,000 Tooling Cost (thousands)	60,000 Total Area (sq. ft.)	90,000 Units/Year Machines Required	90,000 Machinery Cost (thousands)	90,000 Tooling Cost (thousands)	90,000 Total Area (sq. ft.)
100	4-Spindle Drill	$ 25.0	3	$ 75	$ 10.5	300	4	$ 100	$ 13.0	400	9	$ 225	$ 31.5	900	13	$ 575	$ 42.0	1,300
101	Multispindle Drill	47.0	6	282	9.8	720	8	376	13.0	960	15	705	24.4	1,800	22	1,034	34.7	2,640
102	Horizontal Drill	21.0	1	21	.5	180	1	21	.5	180	3	63	1.5	540	4	84	2.0	720
103	N.C. Turret Drill	30.0	2	60	1.8	600	3	90	2.7	900	6	180	10.8	1,800	8	240	15.0	2,400
104	2-Spindle Drill	17.5	2	35	1.8	360	2	35	1.8	360	4	70	3.6	720	6	105	5.4	1,080
105	Drill Press	12.0	4	48	5.0	200	5	60	5.4	250	10	120	12.7	480	14	168	18.0	686
106	Multispindle Drill	85.0	1	85	1.2	300	1	85	1.2	300	1	85	1.2	300	2	170	2.4	600
200	N.C. Vertical Turret Lathe	147.0	5	735	1.8	1,220	7	1,029	2.7	1,720	11	1,890	7.1	4,585	23	3,381	17.4	6,260
201	6-Spindle Chucker	69.0	6	414	14.2	960	8	552	15.4	1,280	15	1,035	28.5	2,400	19	1,311	39.0	3,040
202	Vertical (2) Station Lathe	50.0	3	150	5.2	990	3	150	5.2	990	8	400	14.0	2,640	10	500	19.0	3,300
203	Single-Spindle Chucker	65.0	5	325	2.8	1,875	6	390	5.6	2,250	10	650	10.5	3,750	14	910	10.5	5,250
204	Camshaft Lathe	45.0	3	135	.3	480	3	135	.3	480	6	270	.9	1,560	9	405	.9	1,440
205	Camshaft Lathe	45.0	2	90	.3	320	2	90	.3	320	4	180	.6	640	6	270	.9	960
206	Engine Lathe	27.0	1	27	1.5	160	2	54	3.0	320	3	81	4.5	480	4	108	6.0	640
207	Automatic Lathe	47.0	2	94	2.4	300	3	141	2.4	450	7	329	8.4	1,050	9	423	10.8	1,350
208	6-Spindle Automatic Lathe	40.0	1	40	.6	570	1	40	.6	570	1	40	.6	570	2	80	1.2	1,140
211	N.C. Lathe	110.0	4	440	17.3	1,800	6	660	26.0	2,700	11	1,310	52.0	4,950	16	1,760	72.0	7,200
300	N.C. Work Center	250.0	3	750	1.9	2,640	4	1,000	2.6	3,520	7	1,750	3.8	6,160	9	2,250	7.5	7,920
301	Horizontal Mill	28.0	3	84	3.0	540	4	112	3.7	720	8	224	8.0	1,440	12	336	12.0	2,160
302	Vertical Mill	27.0	1	27	2.9	180	1	27	2.9	180	2	54	5.8	360	3	81	8.7	540
303	Gear Mill	60.0	1	60	.8	720	1	60	.8	720	3	180	2.3	2,160	4	240	3.0	2,880
304	Miller, Center Machine	47.0	1	47	.3	300	1	47	.3	300	2	94	.6	600	2	94	1.2	600
305	Double End Boring Machine	41.0	8	328	2.8	1,200	12	492	4.0	1,800	22	902	7.1	3,300	34	1,394	11.4	5,100
306	Double End Milling Machine	37.5	2	75	3.6	300	3	112	5.4	450	5	187	9.0	750	6	225	10.8	900
307	Boring Machine	58.0	1	58	1.9	450	1	58	1.9	450	2	116	3.7	900	3	174	7.3	1,350
308	Double End Mill and Center	55.0	1	55	.5	300	2	110	1.0	600	3	165	1.5	900	4	220	3.0	1,200
309	Spline Mill	35.0	4	140	.6	800	7	245	1.0	1,400	13	445	1.8	2,600	18	630	2.7	3,600
310	Planer Mill	60.0	1	60	2.2	200	2	120	4.5	400	3	180	6.7	750	4	240	6.7	1,000
311	Milling Machine	22.0	1	22	1.1	130	1	22	1.1	130	2	44	2.2	260	3	66	4.5	390
400	Oil Pan Line	Variable*	1	215	-	2,300	1	215	-	2,300	1	215	-	2,300	1	243	-	2,700
401	Manifold Machine	85.0	1	85	6.6	600	1	85	6.6	600	1	85	6.6	600	1	85	6.6	600
402	Cylinder Block Line	Variable*	1	3,500	-	4,700	1	3,500	-	4,700	1	4,500	-	6,300	1	4,825	-	7,500
403	Crankshaft Line	Variable*	1	250	-	3,500	1	250	-	3,500	1	910	-	4,000	1	1,250	-	4,800
404	Cylinder Head Line	Variable*	1	1,250	-	3,600	1	1,250	-	3,600	1	1,250	-	7,200	1	1,470	-	4,600
405	3-Head Boring Machine	65.0	2	130	4.5	900	2	130	4.5	900	4	260	9.0	1,800	5	325	11.3	2,250
406	Shaft Housing Line	Variable*	1	235	-	2,600	1	235	-	2,600	1	275	-	3,200	1	305	-	3,600
407	Transmission Case Line	Variable*	1	345	-	2,400	1	345	-	2,400	1	390	-	3,200	1	435	-	4,200
409	Clutch Housing Line	Variable*	1	175	-	2,400	1	175	-	2,400	1	230	-	3,000	1	230	-	3,000
411	Riveting Machine	8.0	1	8	.6	136	1	8	.6	136	2	16	1.2	280	2	16	1.2	280
412	Washer	5.0	1	5	-	180	1	5	-	180	1	5	-	180	2	10	-	360
413	Roto Finisher	7.0	1	7	-	200	1	7	-	200	2	14	-	400	2	14	-	400

* Total line cost varies with the number of incremental machining stations necessary to meet production requirements.

TABLE A23-1 (Concluded)

Machine Code	Equipment Description	Cost per Machine (thousands)	20,000 Units/Year Machines Required	20,000 Units/Year Machinery Cost (thousands)	20,000 Units/Year Tooling Cost (thousands)	20,000 Units/Year Total Area (sq. ft.)	30,000 Units/Year Machines Required	30,000 Units/Year Machinery Cost (thousands)	30,000 Units/Year Tooling Cost (thousands)	30,000 Units/Year Total Area (sq. ft.)	60,000 Units/Year Machines Required	60,000 Units/Year Machinery Cost (thousands)	60,000 Units/Year Tooling Cost (thousands)	60,000 Units/Year Total Area (sq. ft.)	90,000 Units/Year Machines Required	90,000 Units/Year Machinery Cost (thousands)	90,000 Units/Year Tooling Cost (thousands)	90,000 Units/Year Total Area (sq. ft.)
415	Paint Line	$ 12.0	1	$ 12	$ -	450	1	$ 12	$ -	450	3	$ 36	$ -	1,350	4	$ 48	$ -	1,800
417	Deburr Machine	10.0	1	10	-	150	1	10	-	150	2	20	-	300	2	20	-	300
418	Camshaft Grinder	31.0	1	31	-	300	1	31	-	300	2	62	-	600	3	93	-	900
419	Camshaft Grinder	35.0	1	35	-	300	1	35	-	300	2	70	-	600	2	70	-	600
420	Gear Shaper	59.0	1	59	.7	775	1	59	1.1	775	2	118	2.0	1,550	2	118	4.2	1,550
421	Induction Hardener	11.0	5	55	2.1	720	7	77	2.5	1,010	16	176	4.5	2,300	25	275	7.3	3,500
422	Buffer	15.0	1	15	-	200	2	30	-	400	3	45	-	600	4	60	-	800
423	Hydrostatic Test	15.0	1	15	-	200	2	30	-	400	3	45	-	600	5	75	-	1,000
424	Cylindrical Grinder	27.0	4	108	-	1,200	5	135	-	1,500	13	351	-	3,900	14	378	-	4,200
425	Gear Hob	40.0	6	240	2.8	1,500	8	320	3.6	2,000	9	360	4.1	1,350	19	760	8.3	1,350
426	Deburr Unit	7.0	1	7	-	150	1	7	-	150	2	14	-	300	3	21	-	450
427	Heat Treat Furnace	100.0	1	100	-	1,200	1	100	-	1,200	2	200	-	2,400	3	300	-	3,600
428	Surface Grinder	28.0	1	28	-	180	1	28	-	180	1	28	-	180	1	28	-	180
429	Internal Grinder	27.0	2	54	-	260	2	54	-	260	4	108	-	720	5	135	-	850
430	Gear Inspection Machine	20.0	2	40	-	160	2	40	-	160	4	80	-	320	5	100	-	400
431	Gear Hob	37.0	4	148	3.8	320	6	222	5.6	480	8	296	7.5	640	13	481	11.3	1,040
432	Shaft Lathe	7.0	1	7	.4	164	1	7	.4	164	1	7	.4	165	1	7	.4	164
502	Balancer	23.0	2	46	1.0	440	2	46	1.3	440	5	115	1.9	1,100	7	161	2.8	1,540
600	Horizontal Broach	34.0	1	34	.5	170	1	34	1.7	170	1	34	1.7	170	2	68	3.4	340
601	Horizontal Broach	45.0	1	45	.3	300	1	45	.5	300	2	90	1.0	600	3	135	1.6	900
602	Vertical Broach	57.0	1	57	8.9	150	1	57	16.2	150	3	171	17.6	450	4	228	25.4	600
	TOTAL																	
	Machining Lines (variable cost equipment)		7	$ 5,970	$	21,500	7	$ 5,970	$	21,500	7	$ 7,770	$	29,200	7	$ 8,758	$	30,400
	General Purpose Machinery for Analyzed Parts		123	6,143	130.8	30,400	158	8,027	172.9	38,055	294	14,780	322.8	72,800	422	21,485	459.8	97,600
	General Purpose Machinery for Parts Not Analyzed*		106	5,275	173.9	26,500	177	8,838	229.9	44,000	348	17,400	429.2	87,000	547	27,345	611.6	137,000
	Inspection Equipment			6		1,200		8		1,700		15		3,000		21		5,000
	Materials Handling Equipment			65				85				175				275		
	Toolroom, Maintenance, and Miscellaneous			81		15,000		92		20,000		212		40,000		266		50,000
	Grand Total		236	$17,540	$304.7	94,600	342	$23,020	$402.8	125,255	649	$40,352	$752.0	232,000	976	$58,150	$1,071.4	320,000

*See Table A23-3 for calculations

TABLE A23-2
MACHINING EQUIPMENT REQUIREMENTS
ACTUAL MAKE-BUY MIX
(U. S. Dollars)

Machine Code	Equipment Description	Cost per Machine (thousands)	20,000 Units/Year Machines Required	20,000 Units/Year Machinery Cost ---- (thousands)	20,000 Units/Year Tooling Cost (thousands) ----	20,000 Units/Year Total Area (sq. ft.)	30,000 Units/Year Machines Required	30,000 Units/Year Machinery Cost ---- (thousands)	30,000 Units/Year Tooling Cost (thousands) ----	30,000 Units/Year Total Area (sq. ft.)	60,000 Units/Year Machines Required	60,000 Units/Year Machinery Cost ---- (thousands)	60,000 Units/Year Tooling Cost (thousands) ----	60,000 Units/Year Total Area (sq. ft.)	90,000 Units/Year Machines Required	90,000 Units/Year Machinery Cost ---- (thousands)	90,000 Units/Year Tooling Cost (thousands) ----	90,000 Units/Year Total Area (sq. ft.)
	General Purpose Machining for Analyzed Parts (from Table A23-1)	$	123	$ 6,143	$130.8	30,400	158	$ 8,027	$172.9	38,055	294	$14,780	$322.8	72,800	422	$21,485	$ 459.8	97,600
	LESS Machinery Not Required for Actual Mix (parts changed to "Buy" at 20,000):																	
101	Multispindle Drill	47	2	94	3.3	240												
200	N.C. Vertical Turret Lathe	147	1	147	.3	240												
201	6-Spindle Chucker	69	1	69	2.4	160												
203	Single-Spindle Chucker	65	1	65	.6	375												
206	Engine Lathe	27	1	27	1.5	160												
207	Automatic Lathe	47	2	94	2.4	300												
208	6-Spindle Automatic Lathe	40	1	40	.6	570												
305	Double-End Boring Machine	41	8	328	2.8	1,200												
306	Double-End Milling Machine	37	2	75	3.6	300												
405	3-Head Boring Machine	65	2	130	4.5	900												
420	Gear Shaper	59	1	59	.7	775												
421	Induction Hardener	11	1	11	.4	150												
422	Buffer	15	1	15		200												
423	Hydrostatic Test	15	1	15		200												
424	Cylindrical Grinder	27	2	55		600												
425	Gear Hob	40	2	80	1.2	500												
601	Horizontal Broach	45	1	45	.6	300												
	Subtotal		30	$ 1,349	$ 24.9	7,170												
	TOTAL																	
	General Purpose Machinery for Analyzed Parts		93	$ 4,794	$105.9	23,230	158	$ 8,027	$172.9	38,055	294	$14,780	$322.8	72,800	422	$21,485	$ 459.8	97,600
	General Purpose Machinery for Parts Not Analyzed*		93	4,794	165.6	23,000	177	8,838	229.9	44,000	348	17,400	429.2	87,000	774	38,700	854.0	194,000
	Machining Lines (from Table A23-1)		7	5,970		21,500	7	5,970		21,500	7	7,770		29,200	7	8,758		30,400
	Inspection Equipment			5		1,000		8		1,700		15		1,000		27		2,000
	Materials Handling Equipment			60				85				175		2,000		375		4,000
	Toolroom, Maintenance, and Miscellaneous			82		15,000		92		20,000		212		40,000		345		60,000
	Grand Total		193	$15,705	$271.5	83,730	342	$23,020	$402.8	125,255	649	$40,352	$752.0	232,000	1,203	$69,690	$1,313.8	388,000

*See Table A23-3 for calculations

TABLE A23-3
CALCULATION OF MACHINING EQUIPMENT FOR COMPONENTS NOT ANALYZED
(U. S. dollars)

		Constant Make-Buy Mix				Actual Make-Buy Mix			
		20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
1.	Total Value of "Make" Parts per Unit (manufacturer's cost from Appendix 2 for machining only)	$ 1,370	$ 1,370	$ 1,370	$ 1,370	$ 1,216	$ 1,370	$ 1,370	$ 1,601
2.	Value of Parts Machined on Lines (from Appendix 1)*	370	370	370	370	370	370	370	370
3.	Value of Parts Machined on General Purpose Equipment (No. 1 - No. 2)	1,000	1,000	1,000	1,000	846	1,000	1,000	1,231
4.	Value of General Purpose Machined Parts Analyzed (from Appendix 1)*	430	430	430	430	330	430	430	430
5.	Per Cent of General Purpose Machined Parts Analyzed (No. 4 ÷ No. 3) (100)	43%	43%	43%	43%	39%	43%	43%	35%
6.	Cost of General Purpose Machinery Required by Parts Analyzed (in thousands) (from Tables A23-1 and A23-2)	$ 6,143	$ 8,027	$ 14,780	$ 21,485	$ 4,794	$ 8,027	$ 14,780	$ 21,485
7.	Scheduled Machine Utilization for Analyzed Parts **	80%	90.4%	94.6%	97.9%	78.5%	90.4%	94.6%	97.9%
8.	Value of Output at 100% Utilization (No. 4 ÷ No. 7) (100)	$ 538	$ 476	$ 455	$ 440	$ 420	$ 476	$ 455	$ 439
9.	Per Cent of General Purpose Machinery Requirements Specified (No. 8 ÷ No. 3) (100)	53.8%	47.6%	45.5%	44.0%	50%	47.6%	45.5%	35.7%
10.	Value of Additional General Purpose Machinery Required (100 - No. 9) (No. 6 ÷ No. 9) (in thousands)	$ 5,275	$ 8,838	$ 17,400	$ 27,345	$ 4,794	$ 8,838	$ 17,400	$ 38,700
11.	Number of Additional Machines (No. 10 ÷ $50,000/machine)	106	177	348	547	93	177	348	774
12.	Additional Floor Space Required (No. 11 x 250 sq. ft. /machine)	26,500	44,000	87,000	137,000	23,000	44,000	87,000	194,000
13.	Estimated Additional Tool Costs (proportionate to analyzed parts)	$173,900	$229,900	$429,250	$611,600	$165,600	$229,900	$429,250	$854,000

° Analyzed parts have been separated into parts machined on lines shown in Table A23-1 and other parts machined on general purpose equipment.

°° Based on machine-hours required vs. 3,072 hours per machine (80% of planned operation).

TABLE A24-1

MACHINING FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
	(square feet)				(square feet)			
Space for Production Machinery (from Appendix 23)	78,400	103,555	189,000	265,000	67,730	103,900	189,000	322,000
Space for Toolroom and Maintenance Equipment (from Appendix 23)	15,000	20,000	40,000	50,000	15,000	20,000	40,000	60,000
Space for Inspection Operations (from Appendix 23)	1,200	1,700	3,000	5,000	1,000	1,700	3,000	6,000
Space for Access Aisles, Offices, and Miscellaneous (25% of total)	32,900	43,200	80,000	110,000	28,770	43,200	80,000	133,000
Total Space Requirements	127,500	168,455	312,000	430,000	112,500	168,800	312,000	521,000
Total Construction Cost @$10.50 per square foot (thousands of U.S. dollars)	$1,340	$1,772	$3,276	$4,515	$1,181	$1,772	$3,276	$5,471

TABLE A25-1
MACHINING INVENTORY COST CALCULATIONS
(U. S. Dollars)

Inventory Category	Scheduled Carrying Time in Weeks	Estimating Rate	Constant Make-Buy Mix 20,000 Units/Year	Constant Make-Buy Mix 30,000 Units/Year	Constant Make-Buy Mix 60,000 Units/Year	Constant Make-Buy Mix 90,000 Units/Year	Actual Make-Buy Mix 20,000 Units/Year	Actual Make-Buy Mix 30,000 Units/Year	Actual Make-Buy Mix 60,000 Units/Year	Actual Make-Buy Mix 90,000 Units/Yea
			(thousands)				(thousands)			
Raw Material	4	8.3% of material cost	$257	$379	$ 722	$1,053	$186	$379	$ 722	$1,452
In-Process	1	2% of variable cost	151	219	416	591	121	219	416	758
Finished	1	2% of variable and facility costs	209	294	548	782	172	294	548	987
Total Inventory Value			$617	$892	$1,686	$2,426	$479	$892	$1,686	$3,197
Capital Cost of Inventory (7 1/2% of Value)			$ 46	$ 67	$ 126	$ 182	$ 36	$ 67	$ 126	$ 240

TABLE A26-1

MACHINING LABOUR REQUIREMENTS

CONSTANT MAKE-BUY MIX

Machine Code	Equipment Description	20,000 Units/Year			30,000 Units/Year			60,000 Units/Year			90,000 Units/Year		
		Operating Man-Hours	Operator Setup Hours	Crew Setup Hours	Operating Man-Hours	Operator Setup Hours	Crew Setup Hours	Operating Man-Hours	Operator Setup Hours	Crew Setup Hours	Operating Man-Hours	Operator Setup Hours	Crew Setup Hours
	Analyzed Parts												
100	4-Spindle Drill	8,310	310		12,465	310		24,930	465		37,495	465	
101	Multispindle Drill	14,760	1,955		22,140	1,955		44,280	840		66,420	1,043	
102	Horizontal Drill	2,600	35		3,900	35		7,800	53		11,700	53	
103	N.C. Turret Drill	5,610	190		8,415	190		16,830	285		25,245	285	
104	2-Spindle Drill	3,788	140		5,667	140		11,364	210		17,073	210	
105	Drill Press	9,260	465		13,820	465		27,780	698		41,670	698	
106	Multispindle Drill	900	75		1,350	75		2,700	113		4,050	113	
200	N.C. Vertical Turret Lathe	15,844	385		23,766	385		47,432	578		71,142	578	
201	6-Spindle Chucker*	3,425	10,225		10,323	10,225		10,274	15,337		15,411	15,338	
202	Vertical (2) Station Lathe*	3,429	775		5,171	775		10,287	1,163		15,431	938	
203	Single-Spindle Chucker	3,689	1,750		5,533	1,750		9,316	2,625		13,974	2,625	
204	Camshaft Lathe	6,070	140		9,105	140		18,210	210		27,315	210	
205	Camshaft Lathe	3,810	130		5,715	130		11,430	195		17,145	195	
206	Engine Lathe	2,580	135		3,870	135		7,740	203		11,610	203	
207	Automatic Lathe	6,240	255		9,360	255		18,720	383		28,082	383	
208	6-Spindle Automatic Lathe*	194	350		290	350		580	525		873	525	
211	N.C. Lathe	10,988	375		16,482	375		32,964	553		48,446	563	
300	N.C. Work Center	6,550	345		9,825	345		19,650	518		29,475	518	
301	Horizontal Mill	7,600	450		11,400	675		22,800	675		34,200	563	
302	Vertical Mill	1,442	250		2,133	250		4,266	375		6,399	375	
303	Gear Mill*	758	35		1,138	35		3,033	53		4,550	53	
304	Miller, Center Machine	1,300	35		1,950	35		3,900	53		5,890	53	
305	Double-End Boring Machine	23,280	230		34,920	230		69,840	345		104,760	345	
306	Double-End Milling Machine	4,200	45		6,300	45		12,600	68		18,900	68	
307	Boring Machine	1,600	250		2,400	250		4,800	375		7,200	375	
308	Double-End Mill and Center	2,700	70		4,050	70		8,100	105		12,150	105	
309	Spline Mill	12,600	150		18,900	150		37,800	225		56,700	225	
310	Planer Mill	2,684	75		4,031	75		8,052	113		12,078	113	
311	Milling Machine	1,500	75		2,250	75		4,500	113		6,750	113	
400	Oil Pan Line**	2,850	-	2,000	4,125	-	2,000	17,250	-	3,000	15,750	-	3,600
401	Manifold Machine	654	637	-	981	637	-	1,962	956	-	2,943	956	-
402	Cylinder Block Line**	58,750	-	7,500	88,125	-	7,500	141,600	-	18,000	141,600	-	18,900
403	Crankshaft Line**	31,100	-	5,000	46,650	-	5,000	96,640	-	9,600	86,790	-	11,700
404	Cylinder Head Line**	12,740	-	4,500	18,116	-	4,500	31,470	-	6,750	28,135	-	7,950
405	3-Head Boring Machine	3,300	135	-	3,950	135	-	9,900	203	-	14,850	203	-
406	Shaft Housing Line**	14,100	-	2,400	21,150	-	2,400	30,600	-	3,600	33,480	-	4,200
407	Transmission Case Line**	24,200	-	3,300	36,300	-	3,300	41,970	-	5,250	43,605	-	6,300
409	Clutch Housing Line**	15,260	-	3,000	22,890	-	3,000	29,370	-	4,800	31,190	-	4,800
411	Riveting Machine	1,100	10		1,650	10		3,300	15		4,950	15	
412	Washer	1,000	10		1,500	10		3,000	15		4,500	15	
413	Roto Finisher	1,000	60		1,500	60		3,000	90		4,500	90	

*Indicates machines assigned more than one per operator.

**Indicates machining lines consisting of several machines manned by a crew of men.

TABLE A26-1 (Concluded)

Machine Code	Equipment Description	20,000 Units/Year			30,000 Units/Year			60,000 Units/Year			90,000 Units/Year		
		Operating Man-Hours	Operator Setup Hours	Crew Setup Hours	Operating Man-Hours	Operator Setup Hours	Crew Setup Hours	Operating Man-Hours	Operator Setup Hours	Crew Setup Hours	Operating Man-Hours	Operator Setup Hours	Crew Setup Hours
415	Paint Line	2,500	60		3,780	60		7,560	90		11,340	90	
417	Deburr Machine	1,300	20		1,950	20		3,900	30		5,850	30	
418	Camshaft Grinder	1,700	35		2,550	35		5,100	53		7,650	53	
419	Camshaft Grinder	1,300	35		1,950	35		3,900	53		5,850	53	
420	Gear Shaper*	610	135		875	135		2,338	68		3,500	68	
421	Induction Hardener*	3,388	200		5,081	200		12,694	300		19,041	300	
422	Buffer	2,580	100		3,870	100		7,740	150		11,610	150	
423	Hydrostatic Test*	1,500	10		2,250	10		3,000	15		4,500	15	
424	Cylindrical Grinder	9,807	83		14,710	83		39,172	124		43,758	124	
425	Gear Hob*	5,000	175		7,138	175		16,119	258		18,935	263	
426	Deburr Unit	1,600	10		2,400	10		4,800	15		7,200	15	
427	Heat Treat	1,610	10		2,415	10		4,800	15		7,200	15	
428	Surface Grinder	540	50		810	50		1,620	75		2,430	75	
429	Internal Grinder	3,510	90		4,265	90		10,260	135		15,390	135	
430	Gear Inspection Machine	3,200	20		4,800	20		9,600	30		14,400	30	
431	Gear Hob*	4,322	150		6,429	150		8,430	225		13,057	225	
432	Shaft Lathe	200	15		300	15		600	23		900	23	
502	Balancer	4,300	80		5,450	80		12,900	110		19,350	130	
600	Horizontal Broach	856	105		1,284	105		2,568	158		3,852	158	
601	Horizontal Broach	1,800	70		2,700	70		5,400	105		8,100	105	
602	Vertical Broach	2,532	140		3,798	140		7,596	210		11,394	210	
	TOTAL												
	Machining Lines	159,000		27,700	237,356		27,700	388,900		51,000	380,550		57,450
	General Purpose Machining for Analyzed Parts	228,920	22,145		345,055	22,370		693,237	30,975		1,019,184	30,877	
	General Purpose Machining for Parts Not Analyzed***	305,545	29,355		457,399	29,630		918,943	41,060		1,351,016	40,930	
	Grand Total	691,465	51,500	27,700	1,039,810	52,000	27,700	2,001,080	72,035	51,000	2,750,750	71,807	57,450
	Inspection												
	Analyzed Parts	15,400			22,800			45,400			66,900		
	Parts Not Analyzed	20,400			30,200			60,600			89,100		
	Total - Inspection	35,800			53,000			106,000			156,000		

*Indicates machines assigned more than one per operator.
**Indicates machining lines consisting of several machines manned by a crew of men.
***Analyzed parts represented 43% of general purpose machining. Man-hours were increased in direct proportion.

TABLE A26-2

MACHINING LABOUR REQUIREMENTS

ACTUAL MAKE-BUY MIX

Machine Code	Equipment Description	20,000 Units/Year Operating Man-Hours	20,000 Units/Year Operator Setup Hours	20,000 Units/Year Crew Setup Hours	30,000 Units/Year Operating Man-Hours	30,000 Units/Year Operator Setup Hours	30,000 Units/Year Crew Setup Hours	60,000 Units/Year Operating Man-Hours	60,000 Units/Year Operator Setup Hours	60,000 Units/Year Crew Setup Hours	90,000 Units/Year Operating Man-Hours	90,000 Units/Year Operator Setup Hours	90,000 Units/Year Crew Setup Hours
	General Purpose Machining for Analyzed Parts (from Appendix 26)	228,920	22,145		345,055	22,370		693,237	30,975		1,019,184	30,877	
	LESS Machinery Not Required for Actual Mix (parts changed to "Buy" at 20,000):												
101	Multispindle Drill	6,100	210										
200	N.C. Vertical Turret Lathe	1,610	300										
201	6-Spindle Chucker	290	1,500										
203	Single-Spindle Chucker	1,100	700										
206	Engine Lathe	2,580	135										
207	Automatic Lathe	6,240	255										
208	6-Spindle Automatic Lathe	192	350										
	Double-End Boring Machine	23,280	230										
306	Double-End Milling Machine	4,200	45										
405	3-Head Boring Machine	3,300	135										
420	Gear Shaper	612	135										
421	Induction Hardener	625	50										
422	Buffer	2,580	100										
423	Hydrostatic Test	1,500	10										
424	Cylindrical Grinder	6,000	48										
425	Gear Hob	1,700	35										
601	Horizontal Broach	1,800	70										
	Subtotal	63,709	4,308										
	TOTAL												
	General Purpose Machining for Analyzed Parts	165,211	17,837		345,055	22,370		693,237	30,975		1,019,184	30,877	
	General Purpose Machining for Parts Not Analyzed*	258,389	27,903		457,399	29,630		918,943	41,060		1,892,816	57,343	
	Machining Lines (from Appendix 26)	159,000		27,700	237,356		27,700	388,900		51,000	380,550		57,450
	Grand Total	582,600	45,740	27,700	1,039,810	52,000	27,700	2,001,080	72,035	51,000	3,292,550	88,220	57,450
	Inspection												
	Analyzed Parts	11,300			22,800			45,400			66,900		
	Parts Not Analyzed	17,500			30,200			60,600			124,200		
	Total - Inspection	28,800			53,000			106,000			191,100		

* Analyzed parts comprise following per cent of general purpose machining: 20,000 - 39%, 30,000 - 43%, 60,000 - 43%, 90,000 - 35%. Man-hours for parts not analyzed were increased in direct proportion.

TABLE A26-3

MACHINING DIRECT LABOUR CALCULATIONS AND DETAILED MANNING TABLE

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR								
1. Machine Operating Man-Hours* (including operator setups)	742,965	1,091,810	2,073,115	2,822,557	628,340	1,091,810	2,073,115	3,380,770
2. Number of Machine Operators (No. 1 ÷ 1,920 hours)	387	569	1,080	1,470	328	569	1,080	1,760
3. Line Setup Man-Hours*	27,700	27,700	51,000	57,450	27,700	27,700	51,000	57,450
4. Number of Line Setup Men (No. 3 ÷ 1,920 hours)	14	14	27	30	14	14	27	30
5. Inspection Man-Hours*	35,800	53,000	106,000	156,000	28,800	53,000	106,000	191,100
6. Number of Inspectors (No. 5 ÷ 1,920 hours)	20	27	55	81	15	27	55	100
7. Absentee and Trainee Replacements (7 1/2% of total direct employees)	34	48	91	127	29	48	91	152
8. Total Direct Employees (No. 2 + 4 + 6 + 7)	455	658	1,253	1,708	386	658	1,253	2,042
9. Other Employees (estimated):								
INDIRECT LABOUR								
Materials Handlers								
In-plant	8	10	18	26	7	10	18	32
Receiving and Shipping	2	2	4	6	2	2	4	7
Storage	2	2	4	6	2	2	4	7
Inspectors								
Receiving	2	3	6	9	2	3	6	12
Layout and Test	2	3	6	9	2	3	6	12
Maintenance								
Tool Makers	9	12	21	29	8	12	21	38
Tool Grinders	8	11	20	28	7	11	20	36
Machine Repair and Oilers	10	14	30	40	7	14	30	50
Crib Attendants	8	11	20	28	7	11	20	36
Sweepers	4	6	10	14	4	6	10	20
Total Indirect Labour	55	74	139	195	48	74	139	250
SUPPORT STAFF								
Supervision								
Superintendent	1	1	1	1	1	1	1	1
Assistant Superintendent	-	-	1	2	-	-	1	3
General Foreman	3	4	6	10	3	4	6	12
Foreman	15	22	40	56	14	22	40	72
Clerical								
Typists	1	1	2	3	1	1	2	3
Plant Clerks	3	4	8	11	3	4	8	15
Expeditors	3	4	6	10	3	4	6	14
Total Support Staff	26	36	64	93	25	36	64	120
Total Machining	536	768	1,456	1,996	459	768	1,456	2,412

* Data taken from Tables A26-1 and A26-2

TABLE A26-4
MACHINING PAYROLL COST CALCULATIONS
(Thousands of U. S. dollars)

	Rate	Constant Make-Buy Mix				Actual Make-Buy Mix			
		20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR									
Operators, Absentees, and Trainees	$ 5.6	$2,357.6	$3,455.2	$ 6,557.6	$ 8,943.2	$1,999.2	$3,455.2	$ 6,557.6	$10,707.2
Line Setup Men	5.9	82.6	82.6	159.3	177.0	82.6	82.6	159.3	177.0
Inspectors	5.6	112.0	151.2	308.0	453.6	84.0	151.2	308.0	560.0
Total Direct Labour		$2,552.2	$3,689.0	$ 7,024.9	$ 9,573.8	$2,165.8	$3,689.0	$ 7,024.9	$11,444.2
INDIRECT LABOUR									
Materials Handlers	5.3	$ 63.6	$ 74.2	$ 137.8	$ 201.4	$ 58.3	$ 74.2	$ 137.8	$ 243.8
Tool Makers and Maintenance	6.2	167.4	229.4	440.2	601.4	136.4	229.4	440.2	768.8
Crib Attendants	5.3	42.4	58.3	106.0	148.4	37.1	58.3	106.0	190.8
Sweepers	4.8	19.2	28.8	48.0	67.2	19.2	28.8	48.0	96.0
Inspectors	5.9	23.6	35.4	70.8	106.2	23.6	35.4	70.8	141.6
Total Indirect Labour		$ 316.2	$ 426.1	$ 802.8	$ 1,124.6	$ 274.6	$ 426.1	$ 802.8	$ 1,441.0
SUPPORT STAFF									
Superintendent	14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8	$ 14.8
Assistant Superintendent	11.8	-	-	11.8	23.6	-	-	11.8	35.4
General Foreman	9.5	28.5	38.0	57.0	95.0	28.5	38.0	57.0	114.0
Foreman	7.4	111.0	162.8	296.0	414.4	103.6	162.8	296.0	532.8
Typists	3.9	3.9	3.9	7.8	117.0	3.9	3.9	7.8	117.0
Clerks	4.2	12.6	16.8	33.6	46.2	12.6	16.8	33.6	63.0
Expeditors	5.0	15.0	20.0	30.0	50.0	15.0	20.0	30.0	70.0
Total Support Staff		$ 185.8	$ 256.3	$ 451.0	$ 761.0	$ 178.4	$ 256.3	$ 451.0	$ 947.0
PAYROLL FRINGE BENEFITS									
Direct Labour	30%	$ 765.0	$1,106.7	$ 2,107.5	$ 2,872.0	$ 650.0	$1,106.7	$ 2,107.5	$ 3,433.0
Indirect Labour	30	95.0	127.0	241.0	338.0	82.0	127.0	241.0	432.0
Support Staff	30	54.2	75.7	134.0	229.0	51.6	75.7	134.0	283.0
Total Fringe Benefits		$ 914.2	$1,309.4	$ 2,482.5	$ 3,439.0	$ 783.6	$1,309.4	$ 2,482.5	$ 4,148.0
Total Payroll Costs		$3,968.4	$5,680.8	$10,761.2	$14,898.4	$3,402.4	$5,680.8	$10,761.2	$17,980.2

TABLE A27-1
ANNUAL MACHINING FACTORY EXPENSES
(Thousands of U.S. dollars)

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
1. Lubricants and Coolants @ $75/machine	$ 17.7	$ 25.6	$ 49.0	$ 73.2	$ 14.4	$ 25.6	$ 49.0	$ 90.2
2. Perishable Tools, Hand Tools, and Gages @ $.25/machine-hour	181.2	262.7	499.2	749.6	148.2	262.7	499.2	923.9
3. Replacement Parts - Jigs and Fixtures @ 8% of tool expense	24.5	32.0	59.9	82.6	21.9	32.0	59.9	101.5
4. Contract Repairs and Calibrations	14.0	16.0	20.0	30.0	12.0	16.0	20.0	45.0
5. Miscellaneous Factory Supplies @ $55/direct man	23.2	32.2	62.0	86.3	19.6	32.2	62.0	103.1
6. Miscellaneous Clerical Supplies @ $200/support man	5.2	7.2	12.8	18.6	5.0	7.2	12.8	24.0
7. Rework and Repairs @ .1% of "make" cost	60.0	90.0	180.0	270.0	54.0	90.0	180.0	330.0
8. Utilities @ $.15/machine/hour	108.0	156.0	300.0	450.0	89.0	156.0	300.0	553.0
9. Heat @ $.20/square foot	25.5	33.8	62.4	86.0	22.5	33.8	62.4	104.2
10. Sundry Expenses	18.0	27.0	54.0	81.0	14.0	27.0	54.0	100.0
11. Contingencies	22.7	32.5	40.7	52.7	19.4	32.5	40.7	65.1
Total	$500.0	$715.0	$1,340.0	$1,980.0	$420.0	$715.0	$1,340.0	$2,440.0

TABLE A28-1
MACHINING PRO FORMA ANNUAL OPERATING COSTS
(Thousands of U.S. dollars)

	Constant Make-Buy Mix				Actual Make-Buy Mix			
	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year	20,000 Units/Year	30,000 Units/Year	60,000 Units/Year	90,000 Units/Year
MATERIALS	$ 3,100	$ 4,560	$ 8,700	$12,690	$2,235	$ 4,560	$ 8,700	$17,490
LABOUR								
Direct	$ 2,552	$ 3,689	$ 7,025	$ 9,574	$2,166	$ 3,689	$ 7,025	$11,444
Indirect	316	426	803	1,125	275	426	803	1,441
Fringe Benefits @30%	860	1,234	2,349	3,210	732	1,234	2,349	3,865
Subtotal - Labour	$ 3,728	$ 5,349	$10,177	$13,909	$3,173	$ 5,349	$10,177	$16,750
OPERATING EXPENSE								
Factory Expense	$ 500	$ 715	$ 1,340	$ 1,980	$ 420	$ 715	$ 1,340	$ 2,440
Support Staff Salaries and Fringe Benefits	240	332	585	990	230	332	585	1,230
Subtotal - Operating Expense	$ 740	$ 1,047	$ 1,925	$ 2,970	$ 650	$ 1,047	$ 1,925	$ 3,670
FACILITY COSTS								
Depreciation								
Building @5%	$ 67	$ 89	$ 164	$ 226	$ 59	$ 89	$ 164	$ 273
Equipment @10%	1,754	2,302	4,035	5,815	1,571	2,302	4,035	6,970
Tooling Amortization @33%	101	133	248	354	90	133	248	434
Taxes and Insurance @5%	944	1,240	2,181	3,133	844	1,240	2,181	3,758
Subtotal - Facility Costs	$ 2,866	$ 3,764	$ 6,628	$ 9,528	$2,564	$ 3,764	$ 6,628	$11,435
CAPITAL COSTS								
Interest on Facilities Investment @7 1/2%	$ 1,133	$ 1,488	$ 2,618	$ 3,760	$1,013	$ 1,488	$ 2,618	$ 4,510
Interest on Inventories @7 1/2%	46	67	126	182	36	67	126	240
Subtotal - Capital Costs	$ 1,179	$ 1,555	$ 2,744	$ 3,942	$1,049	$ 1,555	$ 2,744	$ 4,750
Total Operating Costs	$11,613	$16,275	$30,174	$43,039	$9,671	$16,275	$30,174	$54,095
COST PER UNIT (Actual Dollars)	$ 581	$ 543	$ 502	$ 478	$ 484	$ 543	$ 502	$ 601

TABLE A29-1

ASSEMBLY EQUIPMENT REQUIREMENTS
(U.S. Dollars)

Equipment Description	Equipment Cost (U.S. dollars)	20,000 Units/Year Equipment Required	20,000 Units/Year Machinery Cost	20,000 Units/Year Tooling Cost	60,000 Units/Year Equipment Required	60,000 Units/Year Machinery Cost	60,000 Units/Year Tooling Cost	90,000 Units/Year Equipment Required	90,000 Units/Year Machinery Cost	90,000 Units/Year Tooling Cost
			- - - - (thousands) - - -			- - - - (thousands) - - -			- - - - (thousands) - - -	
Complete Tractor										
Assembly Fixture	$ 5,000	1	$ -	$ 5	2	$ -	$ 10	2	$ -	$ 10
Assembly Conveyor	1,000'	800'	800		1,600'	1,600		1,600'	1,600	
Conveyor Fixtures	50	40		2	80		4	80		4
Drag Line Conveyor	200'	200'	40		400'	80		400'	80	
Paint Line Conveyor	200'	300'	60		600'	120		1,000'	200	
Paint System	200,000	1	200		1	200		2	400	
Overhead Hoist - 1 1/2 ton	400	12	5		24	10		24	10	
Jib Crane - 2 ton	2,000	1	2		2	4		2	4	
Floor Hoist	3,000	2	6		4	12		4	12	
Bench and Hand Tools	100	20		2	64		6	64		6
Impact Wrench	300	35		10	70		7	70		7
Inspection Stations	1,000	8		8	16		16	16		16
Dynamometer Test	25,000	1	25		2	50		3	75	
Repair Stalls	2,000	3		6	5		10	8		16
Tire Mounting and Inflating Stations	1,000	10	10		32	32		47	47	
Total Tractor Assembly			$1,148	$ 33		$2,108	$ 53		$2,428	$ 59
Other Assemblies										
Subassembly Fixtures	$ -	13	$ -	$ 22	13	$ -	$ 22	13	$ -	$ 22
Engine Assembly Fixtures	2,500	100		250	300		750	450		1,125
Transmission Assembly Fixtures	2,500	20		50	50		125	80		200
Engine Assembly Conveyor	300'	1,000'	300		3,000'	900		4,500'	1,350	
Transmission Assembly Conveyor	200'	200'	40		500'	100		800'	160	
Engine Storage Conveyor	100'	400'	40		1,200'	120		1,800'	180	
Transmission Storage Conveyor	100'	400'	40		1,200'	120		1,800'	180	
Engine Test Stand	5,000	15	75		40	200		60	300	
Transmission Test Stand	12,500	2	25		3	38		4	50	
Oil Pump Test Stand	3,000	2	6		2	6		4	12	
Water Pump Test Stand	2,000	1	2		1	2		1	2	
Parts Washer	2,000	5	10		9	18		12	24	
Overhead Hoist - 1 1/2 ton	400	6	2		6	2		6	2	
Jib Crane - 2 ton	1,200	10	12		10	12		10	12	
Bench and Hand Tools	100	100		10	200		20	200		20
Impact Wrench	300	60		18	120		36	120		36
Special Wrench	1,000	1		1	1		1	1		1
Heating Unit	400	6	2		6	2		6	2	
Cold Unit	400	8	3		8	3		8	3	
Arbor Press	500	27	14		27	14		27	14	
Drill Press	16,000	1	16		1	16		2	32	
Engine Paint System	50,000	1	50		1	50		1	50	
Special Bolt Machines	6,500	2	13		2	13		2	13	
Total Other Assemblies			$ 650	$351		$1,616	$ 954		$2,386	$1,404
Total Assembly Equipment			$1,798	$384		$3,724	$1,007		$4,814	$1,463

FIGURE A30-1
TRACTOR ASSEMBLY LINE
OPERATION PROCESS CHART

Operation Code Number	Operation Description
10	Load transmission and differential unit on stand Assemble rear axle housings
20	Transfer unit to assembly line Assemble rockshaft housing, arms, and covers
30	Install control support assembly Install clutch forks and bearings
40	Drop engine in place and assemble to clutch housing Install clutch covers
50	Assemble battery box and cables Install platforms, step, and shields Assemble seat support
60	Install brake valve and pedals Assemble oil pipes
70	Assemble hydraulic pump, pump support, and oil pipes
80	Assemble steering motor Attach frame plate Install fan, muffler, and extension

FIGURE A30-1(Continued)

Code Number	Operation Description
90	Install front axle assembly
100	Inspect and repair
110	Install radiator and hoses Assemble fan shroud
120	Install voltage regulator
130	Assemble oil cooler system
140	Assemble front plate Assemble gas tank and air cleaner Secure oil cooler, radiator, and air cleaner to gas tank
150	Assemble fuel pipes, air intake pipes, and hoses Assemble drawbar and supports
160	Assemble selective control valve and oil pipes Assemble clutch pedal Assemble steering oil pipes Assemble sway control blocks
170	Assemble draft links and lift links for three-point hitch

FIGURE A30-1 (Continued)

Operation	
Code Number	Description
180	Install slave wheels
190	Inspect and repair
200	Assemble fender assemblies and lamp wiring harnesses
210	Attach tractor to drag chain in bonderize and paint system Attach loose components on carriers
220	Bonderize tractor and blow off
230	Paint one side
240	Paint other side
250	Bake
260	Unload paint system
270	Install wheels
280	Assemble cowl and hood Assemble handles

FIGURE A30-1 (Concluded)

Operation	
Code Number	Description
290	Assemble, operator shields and air intakes
300	Install seat Install and connect lamps
310	Test on dynamometer
320	Conduct final inspection
330	Touch up paint
340	Repair and customize
350	Drive to shipping storage
360	Store for shipment

TABLE A31-1

ASSEMBLY FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

ASSEMBLY OPERATIONS	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
	(square feet)		
Tractor Assembly	52,000	104,000	120,000
Tire Assembly	10,000	32,000	47,000
Engine Assembly	15,000	45,000	67,500
Engine Subassemblies (estimated)	3,000	9,000	12,000
Transmission Assembly	2,000	5,000	8,000
Transmission Subassemblies (estimated)	1,000	3,000	4,000
Subtotal Space for Assembly Operations	83,000	198,000	258,500
Space for Maintenance	1,000	2,000	3,000
Space for Inspection Operations	1,500	4,000	6,000
Space for Access Aisles, Offices, and Miscellaneous (25% of total)	28,500	68,000	87,500
Total Space Requirement	114,000	272,000	355,000
Total Construction Cost @$10.50 per square foot (thousands of U.S. dollars)	$1,197	$2,856	$3,728

APPENDIX 32

TABLE A32-1
ASSEMBLY INVENTORY COST CALCULATIONS
(U. S. Dollars)

Inventory Cost Summary

Category	Scheduled Carrying Time in Weeks	Estimating Rate	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
			(thousands)		
Purchased Components	4	8 1/3% of annual purchases	$3,537	$ 9,136	$10,630
In-Process Units	1	2% of components' costs and assembly variable cost	1,390	3,698	5,070
Completed Units	1	2% of components' costs and assembly variable and facility costs	1,400	3,722	5,101
Total Inventory Value			$6,327	$16,556	$20,801
Annual Capital Cost of Inventory (7 1/2% of Value)			$ 475	$ 1,242	$ 1,560

TABLE A33-1
ASSEMBLY LABOUR REQUIREMENTS
(Man-Hours)

Name of Assembly	20,000 Units/Year			60,000 Units/Year			90,000 Units/Year		
	Assembly Hours	Setup Hours	Inspection Hours	Assembly Hours	Setup Hours	Inspection Hours	Assembly Hours	Setup Hours	Inspection Hours
Tractor Assembly	86,900	945	8,000	246,000	630	24,000	361,600	630	36,000
Rear Axle Housing	9,800	188	800	27,600	125	2,400	40,600	125	3,600
Planet Pinion Carrier	5,000	30	300	14,100	20	900	20,800	20	1,350
Rockshaft Housing	4,200	105	400	12,000	70	1,200	17,600	70	1,800
Rockshaft Control Valve	1,900	90	200	5,400	60	600	8,000	60	900
Control Support	4,700	90	400	13,200	60	1,200	19,400	60	1,800
Dash Assembly	1,000	45	100	3,000	30	300	4,400	30	450
Instrument Panel	700	15	100	2,100	10	300	3,000	10	450
Control Support Cover	300	15	-	900	10	-	1,300	10	-
Clutch	2,600	75	200	7,500	50	600	11,000	50	900
Brake Valve and Pedal	3,900	82	400	11,100	55	1,200	16,300	55	1,800
Front Axle	7,500	210	600	21,300	140	1,800	31,300	140	2,700
Front Wheel Hub	800	30	-	2,400	20	-	3,500	20	-
Gas Tank	1,100	30	-	3,000	20	-	4,400	20	-
Fender	1,300	150	200	3,600	100	600	5,300	100	900
Hood	1,700	30	200	4,800	20	600	7,000	20	900
Front Tire and Wheel	8,500	50	-	24,000	50	-	35,300	50	-
Rear Tire and Wheel	21,200	125	-	60,000	125	-	88,200	125	-
Rear Wheel	4,500	105	-	12,600	70	-	18,500	70	-
Engine	78,400	1,400	6,000	222,000	1,400	18,000	326,300	1,400	27,000
Crankshaft and Gear	1,600	45	100	4,500	45	300	6,600	45	450
Piston and Rod	7,000	45	600	19,800	45	1,800	29,100	45	2,700
Camshaft and Gear	1,200	30	100	3,300	30	300	4,900	30	450
Cylinder Head	6,800	112	600	19,200	112	1,800	28,200	112	2,700
Rocker Arm	2,500	45	200	7,200	45	600	10,600	45	900
Oil Cooler	2,000	30	100	5,700	30	300	8,400	30	450
Water Pump	3,100	98	300	8,700	98	900	12,800	98	1,350
Ventilator Pump	2,300	45	200	6,600	45	600	9,700	45	900
Differential and Transmission	48,800	750	4,000	138,000	750	12,000	202,900	750	18,000
Countershaft	1,000	68	100	2,700	68	300	4,000	68	450
Transmission Drive Shaft	6,500	105	600	18,300	105	1,800	26,900	105	2,700
Differential	6,300	75	600	17,700	75	1,800	26,000	75	2,700
Total	335,100	5,258	25,400	948,300	4,513	76,200	1,394,000	4,513	114,300

TABLE A33-2

ASSEMBLY DIRECT LABOUR CALCULATIONS AND DETAILED MANNING TABLE

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR			
1. Assembly Man-Hours (from Table A33-1)	335,100	948,300	1,394,000
2. Number of Assemblers (No. 1 ÷ 1,920 hours)	175	494	726
3. Setup Man-Hours (from Table A33-1)	5,258	4,513	4,513
4. Number of Setup Men (No. 3 ÷ 1,920 hours)	3	3	3
5. Inspection Man-Hours (from Table A33-1)	25,400	76,200	114,300
6. Number of Inspectors (No. 5 ÷ 1,920 hours)	14	40	60
7. Absentees and Trainee Replacements (7 1/2% of total direct employees)	17	43	64
8. Total Direct Employees (No. 2 + 4 + 6 + 7)	209	580	853
9. Other Employees (estimated):			
INDIRECT LABOUR			
Materials Handlers			
In-Plant	10	31	46
Receiving	4	10	15
Inspectors			
Receiving	4	10	15
Layout	2	6	10
Maintenance			
Fixture Repair, Machine Repair, and Oilers	10	25	35
Crib Attendants	2	6	10
Sweepers	4	12	18
Total Indirect Labour	36	100	149
SUPPORT STAFF			
Supervision			
Superintendent	1	1	1
Assistant Superintendent	1	1	2
General Foreman	3	7	10
Foreman	12	34	50
Clerical			
Typists	2	2	3
Plant Clerks	2	3	5
Expeditors	2	6	8
Total Support Staff	23	54	79
Total Assembly Staff	268	734	1,081

TABLE A33-3
ANNUAL ASSEMBLY PAYROLL COST CALCULATIONS
(Thousands of U.S. dollars)

	Rate	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
DIRECT LABOUR				
Assemblers, Absentees, and Trainees	$ 5.6	$1,075.2	$3,007.2	$4,424.0
Setup Men	5.9	17.7	17.7	17.7
Inspectors	5.6	78.4	224.0	336.0
Total Direct Labour		$1,171.3	$3,248.9	$4,777.7
INDIRECT LABOUR				
Materials Handlers	5.3	$ 74.2	$ 217.3	$ 323.3
Inspectors	5.9	35.4	94.4	147.5
Machine Maintenance	6.2	62.0	155.0	217.0
Crib Attendants	5.3	10.6	31.8	53.0
Sweepers	4.8	19.2	57.6	86.4
Total Indirect Labour		$ 201.4	$ 556.1	$ 827.2
SUPPORT STAFF				
Superintendent	14.8	$ 14.8	$ 14.8	$ 14.8
Assistant Superintendent	11.8	11.8	11.8	23.6
General Foreman	9.5	28.5	66.5	95.0
Foreman	7.4	88.8	251.6	370.0
Typists	3.9	7.8	7.8	11.7
Clerks	4.2	8.4	12.6	21.0
Expeditors	5.0	10.0	30.0	40.0
Total Support Staff		$ 170.1	$ 395.1	$ 576.1
PAYROLL FRINGE BENEFITS				
Direct Labour	30%	$ 351.4	$ 974.7	$1,433.3
Indirect Labour	30	60.4	166.8	248.2
Support Staff	30	51.0	118.5	172.8
Total Fringe Benefits		$ 462.8	$1,260.0	$1,854.3
Total Payroll Costs		$2,005.6	$5,460.1	$8,035.3

TABLE A34-1
ANNUAL ASSEMBLY FACTORY EXPENSES
(Thousands of U. S. dollars)

		20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
1.	Fuel, Lubricants, Coolants, and Paint @ $25 per tractor *	$500.0	$1,500.0	$2,250.0
2.	Perishable Tools, Hand Tools, and Gages @ $50 per direct man	9.9	29.0	43.5
3.	Replacement Parts - Test Stands and Fixtures @ 1% of total tooling	3.8	10.1	14.6
4.	Contract Repairs and Calibrations	20.0	40.0	50.0
5.	Miscellaneous Factory Supplies @ $75/direct man	14.8	43.5	65.3
6.	Miscellaneous Clerical Supplies @ $200/support man	4.6	10.8	15.8
7.	Rework and Repairs @ 2% of direct Labour	22.1	65.0	97.5
8.	Utilities @ $.15/assembly hour	47.4	142.2	213.4
9.	Heat @ $.20/square foot	22.8	54.4	71.0
10.	Sundry Expenses	15.0	30.0	40.0
11.	Contingencies	16.6	50.0	72.9
	Total Annual Factory Expense	$677.0	$1,975.0	$2,934.0

*	Fuel - 5 gallons @ $.20	=	$ 1.00
	Engine Oil - 10 quarts @ $.20	=	2.00
	Transmission Oil - 22 quarts @ $.25	=	5.50
	Antifreeze - 2 gallons @ $1.00	=	2.00
	Paint	=	4.00
	Hydraulic System - 40 quarts @ $.25	=	10.00
	Other	=	0.50
			$25.00

TABLE A35-1
ASSEMBLY PRO FORMA ANNUAL OPERATING COSTS
(Thousands of U. S. dollars)

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
LABOUR			
Direct	$1,171.3	$ 3,248.9	$ 4,777.7
Indirect	201.4	556.1	827.2
Fringe Benefits @30%	411.8	1,141.5	1,681.5
Subtotal - Labour	$1,784.5	$ 4,946.5	$ 7,286.4
OPERATING EXPENSES			
Factory Expense	$ 677.0	$ 1,975.0	$ 2,934.0
Support Staff Salaries and Fringe Benefits	221.1	513.6	748.9
Subtotal - Operating Expenses	$ 898.1	$ 2,488.6	$ 3,682.9
FACILITIES COSTS			
Depreciation			
Building @5%	$ 60.0	$ 142.8	$ 186.4
Equipment @10%	178.8	369.2	476.7
Tooling Amortization @33%	126.7	332.3	482.8
Insurance and Taxes @5%	149.8	329.0	427.1
Subtotal - Facilities Costs	$ 515.3	$ 1,173.3	$ 1,573.0
CAPITAL COSTS			
Interest on Facilities Investment @7 1/2%	$ 179.7	$ 394.8	$ 512.5
Interest on Inventories @7 1/2%	475.0	1,242.0	1,560.0
Subtotal - Capital Costs	$ 654.7	$ 1,636.0	$ 2,072.5
Total Plant Costs	$3,852.6	$10,244.4	$14,614.8
Cost per Unit (Actual Dollars)	$ 192.6	$ 171.0	$ 162.3

TABLE A36-1
OFFICE SUPPORT AND ADMINISTRATIVE STAFFING REQUIREMENTS
DETAILED MANNING TABLE

Function	20,000 Units/Year			60,000 Units/Year			90,000 Units/Year		
	Managers and Superintendents	Supervision and Technical	Clerical and Hourly	Managers and Superintendents	Supervision and Technical	Clerical and Hourly	Managers and Superintendents	Supervision and Technical	Clerical and Hourly
General Administrative Managers and Staff	6	-	6	8	-	9	8	2	10
Accounting	1	4	20	3	10	45	3	18	60
Timekeeping and Payroll	-	2	6	1	4	18	1	6	24
Data Processing	1	21	38	2	27	70	4	34	92
Production Control	1	6	12	1	18	36	2	24	50
Purchasing	1	4	5	1	10	14	2	14	20
Material Control	1	6	12	1	16	36	2	24	50
Allowance for Absentees and Trainee Replacements	-	-	8	-	-	18	-	-	25
Total Office Support and Administrative	11	43	107	17	85	246	22	122	331

TABLE A36-2
ANNUAL OFFICE SUPPORT AND ADMINISTRATIVE
PAYROLL COST CALCULATIONS
(Thousands of U. S. dollars)

Staff Position	Rate	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Managers	$25.0	$ 150.0	$ 200.0	$ 200.0
Superintendents	16.8	84.0	151.2	235.2
Supervision and Technical	8.4	361.2	714.0	1,024.8
Clerical and Hourly	6.0	642.0	1,476.0	1,986.0
Total Staff Payroll		$1,237.2	$2,541.2	$3,446.0
Payroll Fringe Benefits				
Fringe Benefits	30%	$ 371.2	$ 762.4	$1,033.8
Total Payroll Costs		$1,608.4	$3,303.6	$4,479.8

TABLE A37-1
OFFICE SUPPORT AND ADMINISTRATIVE FACILITY REQUIREMENTS
(U. S. Dollars)

	20,000 Units/Year			60,000 Units/Year			90,000 Units/Year		
Category	Number of People	Equipment Cost* (000)	Area** (sq. ft.)	Number of People	Equipment Cost* (000)	Area** (sq. ft.)	Number of People	Equipment Cost* (000)	Area** (sq. ft.)
Managers	5		1,250	8		2,000	8		2,000
Superintendents	6		1,500	9		2,250	14		3,500
Supervision and Technical	43		4,300	85		8,500	122		12,200
Data Processing Installation		$20			$ 40			$ 50	
Clerical and Hourly	107	54	5,350	246	123	12,300	331	166	16,550
Totals	161	$74	12,400	348	$163	25,050	475	$216	34,250

* Based on $500 per clerical or hourly paid employee except in data processing, where special estimate was prepared.

** Based on 250 square feet for managers and superintendents, 100 square feet for supervisors and technical personnel, and 50 square feet for clerical and hourly paid employees.

TABLE A38-1
OFFICE SUPPORT AND ADMINISTRATIVE FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
	(square feet)		
Space for Offices (from Table A37-1)	12,400	25,050	34,250
Space for Lobbies, File Rooms, and Conference Rooms (10% of total)	1,600	3,340	4,550
Space for Aisles and Hallways (15% of total)	2,400	5,010	6,800
Total Space Requirements	16,400	33,400	45,600
Total Construction Cost @$30 per square foot (thousands of U.S. dollars)	$492	$1,002	$1,368

TABLE A39-1
PALLETS FOR MOVEMENT OF MATERIALS

Purpose	Pallets per 100 Tractors
To Receive Purchased Material	
Machining Stock	100
Assembly Stock	300
Stamping Stock	25
Tires	100
Subtotal Receiving	525
To Move In-Process Material	
Castings	
Move to Rack Storage	300
Move to Floor Storage	50
Machining Stock	450
Stampings	150
Subtotal In-Process Moving	950
To Move Assembly Materials	
Make Components	600
Purchased Components (except tires)	300
Tire and Wheel Assemblies	200
Subtotal Assembly Moving	1,100

TABLE A39-2
FLOOR STORAGE SPACE REQUIREMENTS

Space Required per Pallet

		In Stacker Storage (square feet)	In Pallet Rack (square feet)
1.	Area per Pallet Stack	16	16
2.	Access Aisle Area per Pallet Stack	10	16
3.	Floor Area per Pallet Stack (No. 1 + No. 2)	26	32
4.	Pallets per Average Stack	9	3
5.	Area per Pallet (rounded) (No. 3 ÷ No. 4)	3	11

Steel Storage Space Required

6.	Steel per Pallet Load		5000 pounds	
7.	Steel per Tractor (per Appendix 14)		1000 pounds	
8.	Pallets per Tractor (No. 6 ÷ No. 7)		.2	
9.	Inventory on Hand (weeks)		6	
10.	Volume	20,000	60,000	90,000
11.	Pallets on Hand (No. 8 x No. 9 x 5 x daily production)	500	1,500	2,250
12.	Area Required (No. 11 x 11 sq. ft.) (from No. 5 above)	5,500	16,500	25,000

Tire and Wheel Storage

13.	Pallets per Tractor (from Table A39-1)		2	
14.	Inventory on Hand (weeks)		4	
15.	Volume	20,000	60,000	90,000
16.	Pallets on Hand (No. 13 x No. 14 x 5 x daily production)	3,320	10,000	15,000
17.	Area Required (No. 16 x 6 sq. ft.) (1/2 of No. 5 above)	20,000	60,000	90,000

Floor Stacked Castings

18.	Pallets per Tractor		.5	
19.	Inventory on Hand (weeks)		1	
20.	Volume	20,000	60,000	90,000
21.	Pallets on Hand (No. 18 x 19 x 5 x daily production)	200	600	900
22.	Area Required (No. 21 x 11 sq. ft.)(from No. 5 above)	2,200	6,600	9,900
23.	Total Floor Storage Space Requirements (No. 12 + No. 17 + No. 22)	27,700	83,100	124,900

TABLE A39-3

AUTOMATED STORAGE SYSTEM SPACE REQUIREMENTS

Material	Pallets per 100 Tractors*	Weeks of Inventory on Hand	Annual Volume / Volume per Day	20,000 Units / 83 Units	60,000 Units / 250 Units	90,000 Units / 375 Units
					Pallet Spots Required	
Receiving Storage						
Machining Stock	100	4		1,660	5,000	7,500
Assembly Stock	300	4		4,980	15,000	22,500
In-Process Materials						
Castings (in racks)	300	1		1,245	3,750	5,625
Machining Stock	450	1		1,868	5,625	8,438
Stampings	150	1		622	1,875	2,812
Assembly Materials (except tires)						
Make Components	600	1		2,490	7,500	11,250
Buy Components	300	1		1,245	3,750	5,625
Other				90	200	250
	Total Pallet Spots Required			14,200	42,700	64,000
	Area Required @3 square feet per pallet			42,600	128,100	192,000

*From Table A39-1

APPENDIX 39

TABLE A39-4
ASSEMBLY STORAGE SPACE REQUIREMENTS

	Area per Tractor (sq. ft.)	Weeks of Inventory on Hand		20,000 Units	60,000 Units	90,000 Units
			Annual Volume	20,000 Units	60,000 Units	90,000 Units
			Volume per Day	83 Units	250 Units	375 Units
				Area Required (sq. ft.)		
Inside Assembly Storage						
Completed Engines	10	1		4,150	12,500	18,750
Completed Transmissions	18	1		7,500	22,500	37,500
		Total Inside Assembly Storage		11,650	35,000	56,250
Outside Assembly Storage						
Completed Tractors	150	1		62,250	187,500	281,250
		Total Assembly Storage		73,900	222,500	337,500

TABLE A40-1
EVALUATION OF COMPONENT STORAGE SYSTEMS
(Thousands of U.S. dollars)

60,000-Unit Volume

	Stacker System	Fork Truck and Rack System
Space Required		
Required Pallets Spots in Storage	42,700	42,700
Area Required (sq. ft.)	128,000	470,000
Building Cost*	$1,088	$3,055
Annual Building Depreciation @5%	$ 54	$ 153
Equipment Comparison		
Racks Required (units)	42,700	5,340
Rack System Cost	$5,338	$1,602
Trucks Required @30 moves/hour	-	18
Truck Cost	-	$ 270
Total Equipment Cost	$5,338	$1,872
Annual Equipment Depreciation**	$ 534	$ 214
Labor Cost		
Manpower Required	16	56
Annual Labour Cost (including fringe benefits)	$ 128	$ 448
Capital Cost		
Annual Cost of Invested Capital @7 1/2% of Building and Equipment	$ 386	$ 296
Total Annual Cost	$1,102	$1,111

* Building Costs
Stacker System @$8.50 per square foot
Fork Truck and Rack System @$6.50 per square foot

** Depreciation Rates
Stacker System @10%
Rack System @10%
Fork Trucks @20%

TABLE A41-1
MATERIALS HANDLING EQUIPMENT REQUIREMENTS SUMMARY
(U. S. Dollars)

Item	Equipment Description	Cost of Equipment	20,000 Units/Year		60,000 Units/Year		90,000 Units/Year	
			Equipment Required	Equipment Cost (000)	Equipment Required	Equipment Cost (000)	Equipment Required	Equipment Cost (000)
1	Towline Conveyor	$150/foot	3,000	$ 450	6,000	$ 900	7,500	$ 1,125
2	Towline On and Off Spurs	$ 1,000	30	30	50	50	75	75
3	Towline Carts	$ 500	350	175	650	325	800	400
4	Pallet Transfer Trucks	$10,000	3	30	8	80	12	120
5	Storage System with Automated Retrieval	$125/opening	14,000	1,775	42,000	5,338	64,000	8,000
6	Materials Handling Trucks	$15,000	2	30	7	105	10	150
7	Pallet Storage Racks	$ 300	100	30	300	90	450	135
8	Tubs	$ 200	1,000	200	3,000	600	4,500	900
9	Steel Flats	$ 75	2,000	150	6,000	450	9,000	675
10	Tire Handling Trucks	$15,000	2	30	6	90	8	120
11	Tire Handling Conveyor	$100/foot	1,000	100	3,200	320	4,700	470
12	Steel Handling Crane	$50,000	1	50	2	100	3	150
	Totals			$3,050		$8,448		$12,320

TABLE A41-2
MATERIALS HANDLING EQUIPMENT CALCULATIONS

Item*	Equipment	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
1.	Towline Length (feet)	3,000	6,000	7,500
2.	Towline Spurs by Area			
	Receiving	4	8	10
	Component Warehousing	4	8	10
	Foundry	4	6	8
	Stamping	4	6	10
	Machining	4	6	10
	Assembly	6	12	20
	Other	4	4	7
	Total Towline Spurs	30	50	75
3.	Towline Carts 1 per 10 feet of towline length + 50 spares	350	650	800
4.	Pallet Transfer Trucks			
	Pallet Transfers @22/tractor produced	143/hour	440/hour	660/hour
	Transfer Trucks @60 moves/hour	3	8	12
7.	Materials Handling Trucks Pallet Movement per Hour			
	Receiving @4/tractor	26	80	120
	Castings @.5/tractor	4	10	15
	Steel @.2/tractor	1	4	6
	Supplies @.2/tractor	1	4	6
	Total Pallet Movement - Other	32	98	147
	Fork Trucks Required @15 moves/hour	2	7	10
11.	Tire Handling Trucks			
	Tire and Wheel Movement per Hour			
	Total Pallet Movement @2/tractor	13	40	60
	Fork Trucks Required @7.5 moves/hour	2	6	8
12.	Tire Handling Conveyor 100 feet/station	1,000	3,200	4,700

* Item number refers to entry on Table A41-1

TABLE A42-1

MATERIALS HANDLING FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
		(square feet)	
Space for Steel Storage	5,500	16,500	25,000
Space for Tire and Wheel Storage	20,000	60,000	90,000
Space for Floor Stacked Castings	2,200	6,600	9,900
Space for Automated Storage System	42,600	128,000	192,000
Space for Marshalling and Transfer Loads	4,000	12,000	20,000
Space for Engine and Transmission Storage	11,650	35,000	56,250
Space for Lubricants and Supplies	10,000	30,000	45,000
Space for Receiving Docks	3,400	5,000	8,000
Space for Shipping Docks	24,000	36,000	54,000
Space for Access Aisles and Service Areas (15% of total)	21,650	55,900	89,850
Total Space Requirements	145,000	385,000	590,000
Total Construction Cost @$6.50 per square foot* (thousands of U.S. dollars)	$1,028	$2,760	$4,220

* Automated storage system is calculated at $8.50 per square foot.

TABLE A43-1
MATERIALS HANDLING STAFFING REQUIREMENTS
DETAILED MANNING TABLE

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Receiving Manpower			
Receiving Clerk	1	2	2
Truck Drivers	4	14	20
Inspector	2	4	6
Utility	2	2	2
Total Receiving Manpower	9	22	30
Storage System Manpower			
Crane Operators	4	6	10
Material Handlers	4	8	12
Utility and Relief	2	2	4
Total Storage System Manpower	10	16	26
Shipping Manpower			
Shipping Clerk	2	4	6
Shipper	10	32	48
Inspector	2	4	6
Utility	2	4	6
Total Shipping Manpower	16	44	66
Miscellaneous Handling Manpower			
Tire and Wheel Handling	12	36	44
Steel Handling	4	12	16
Miscellaneous Supplies	2	4	8
Trash Handling	4	12	16
Total Miscellaneous Handling Manpower	22	64	84
Allowance for Absentee and Trainee Replacements	5	12	17
Total Materials Handlers	62	158	223
Supervision and Clerical			
Superintendent	-	1	1
Assistant Superintendent	1	1	2
General Foreman	-	2	4
Foreman	4	10	15
Typists	1	3	5
Expeditors	2	4	6
Total Supervision and Clerical	8	21	33
Total Materials Handling Staff	70	179	256

TABLE A43-2
MATERIALS HANDLING PAYROLL COST CALCULATIONS
(Thousands of U. S. dollars)

Position	Rate	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Material Handlers	$ 5.6	$347.2	$ 884.8	$1,248.8
Superintendent	14.8	-	14.8	14.8
Assistant Superintendent	11.8	11.8	11.8	23.6
General Foreman	9.5	-	19.0	38.0
Foreman	7.4	29.6	74.0	111.0
Clerical and Expeditors	5.0	15.0	35.0	55.0
Total Staff Payroll		$403.6	$1,039.4	$1,491.2
Payroll Fringe Benefits				
Fringe Benefits	30%	$121.1	$ 311.8	$ 447.4
Total Payroll Costs		$524.7	$1,351.2	$1,938.6

TABLE A44-1
FACTORY SUPPORT STAFFING REQUIREMENTS
DETAILED MANNING TABLE

	20,000 Units/Year			60,000 Units/Year			90,000 Units/Year		
Function	Managers and Superintendents	Supervision and Technical	Clerical and Hourly	Managers and Superintendents	Supervision and Technical	Clerical and Hourly	Managers and Superintendents	Supervision and Technical	Clerical and Hourly
Plant Security	1	4	20	2	8	60	2	12	80
Building and Grounds	1	5	22	1	10	60	2	18	80
Maintenance and Utilities	3	12	100	6	18	300	6	24	400
Quality Control	-	6	2	1	15	6	1	20	8
Industrial Engineering	1	10	5	1	30	10	2	40	15
Process Engineering	-	6	2	1	15	6	1	20	8
Plant Engineering	1	6	2	1	15	6	1	20	8
Personnel Administration	-	2	8	1	6	24	2	8	32
Employment	1	2	1	1	4	2	1	6	3
Employee Training	-	2	15	1	6	30	1	10	45
Health and Safety	1	4	2	1	10	5	1	15	8
Allowance for Absentees and Trainee Replacements	-	-	15	-	-	41	-	-	56
Total Factory Support Staff	9	59	194	17	137	550	20	193	743

TABLE A44-2
ANNUAL FACTORY SUPPORT
PAYROLL COST CALCULATIONS
(Thousands of U. S. dollars)

Staff Position	Rate	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Superintendents	$16.8	$ 151.2	$ 285.6	$ 336.0
Supervision and Technical	9.0	531.0	1,233.0	1,737.0
Clerical and Hourly	6.5	1,261.0	3,575.0	4,829.5
Total Staff Payroll		$1,943.2	$5,093.6	$6,902.5

TABLE A45-1
FACTORY SUPPORT FACILITY REQUIREMENTS SUMMARY
(U. S. Dollars)

	Equipment Cost (thousands)	Area Required (sq. ft.)	20,000 Units/Year Number of People	20,000 Units/Year Equipment Cost (thousands)	20,000 Units/Year Area (sq. ft.)	60,000 Units/Year Number of People	60,000 Units/Year Equipment Cost (thousands)	60,000 Units/Year Area (sq. ft.)	90,000 Units/Year Number of People	90,000 Units/Year Equipment Cost (thousands)	90,000 Units/Year Area (sq. ft.)
Office											
Superintendents		250	9		2,300	17		4,250	20		5,000
Supervision and Technical	$.5/man	100	59	$ 30	5,900	137	$ 70	13,700	193	$ 97	19,300
Clerical	.5/man	50	40	20	2,000	95	48	4,750	137	68	6,900
Security	.5/man	50	20	10	1,000	60	30	3,000	80	40	4,000
Total Office			128	$ 60	11,200	309	$ 148	25,700	430	$ 205	35,200
Maintenance											
Shop Equipment	2.5/man	100	110	$250	10,000	330	$ 825	33,000	440	$1,100	44,000
Trucks	15.0/truck			45			135			180	
Garage Space					1,000			3,000			4,000
Product Reclaiming Equipment				100	1,000		250	3,000		350	4,000
Total Maintenance				$395	12,000		$1,210	39,000		$1,630	52,000
Building and Grounds			24			65			86		
Industrial Sweepers	15/item			$ 30			$ 90			$ 105	
Truck and Plows	20/item			40			120			140	
Storerooms				2	1,000		6	3,000		9	4,000
Garage Space				5	1,000		15	3,000		23	4,000
Total Building and Grounds				$ 77	2,000		$ 231	6,000		$ 277	8,000
Technical Services											
Quality Control				$ 20	2,000		$ 80	8,000		$ 120	12,000
Engineering				20	2,000		80	8,000		120	12,000
Total Technical Services				$ 40	4,000		$ 160	16,000		$ 240	24,000
Industrial Relations											
Dispensary				$ 10	2,000		$ 20	4,000		$ 30	6,000
Lunchroom				10	10,000		30	30,000		45	45,000
Recreation				5	4,000		10	6,000		15	9,000
Total Industrial Relations			—	$ 25	16,000	—	$ 60	40,000	—	$ 90	60,000
Subtotal - Factory Support Facility Costs			262	$597	45,200	704	$1,809	126,700	956	$2,442	179,200
Site Preparation Costs (from Table A45-2)			—	350	—	—	675	—	—	975	—
Totals			262	$947	45,200	704	$2,484	126,700	956	$3,417	179,200

TABLE A45-2
SITE PREPARATION COSTS
(Thousands of U.S. dollars)

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Site Size (acres)	40	90	130
Land @$2,500 per acre	$100	$225	$325
Services to Property Line: Water Sewers, electrical Sprinkler mains Electrical	80	120	180
Grading, drainage, and paving	50	100	150
Rail siding	60	120	180
Fencing	25	45	60
Miscellaneous	35	65	80
Total Site Preparation Costs	$350	$675	$975

TABLE A46-1
FACTORY SUPPORT FLOOR SPACE AND CONSTRUCTION COST CALCULATIONS

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
	---------- (square feet) ----------		
Space for Offices	11,200	25,700	35,200
Space for Maintenance	12,000	39,000	52,000
Space for Building and Grounds	2,000	6,000	8,000
Space for Technical Services	4,000	16,000	24,000
Space for Industrial Relations	16,000	40,000	60,000
Space for Access Aisles and Hallways (25% of total)	14,800	43,300	60,800
Total Space Requirements	60,000	170,000	240,000
Total Construction Cost @$10.50 per square foot (thousands of U. S. dollars)	$630	$1,785	$2,520

TABLE A47-1
ANNUAL ADMINISTRATIVE AND SUPPORT EXPENSES SUMMARY
(U.S. Dollars)

		20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
		- - - - - - - - (thousands)	- - - - - - - -	
1.	Equipment Rental (from Table A47-2)	$ 355	$ 680	$ 815
2.	Lubricants, Fuel, and Operating Cost for All Trucks (20% of value)	53	166	235
3.	Perishable Tools, Equipment Parts, and Maintenance Equipment Repairs (1% of maintenance equipment cost)	25	83	110
4.	Maintenance Materials @ $5,000/worker (80% of maintenance labour)	500	1,500	2,000
5.	Operating Aids and Shipping Supplies (tools, instruction books, protective covering, and blocking) @ $10 per unit	200	600	900
6.	Janitorial and Groundskeeping Supplies	18	30	43
7.	Utilities	30	80	120
8.	Heat @$.20 / square foot*	30	80	120
9.	Sundry Expenses	40	65	80
10.	Contingencies	29	86	117
	Total Annual Administrative and Support Expense	$1,280	$3,370	$4,540

* Storage areas calculated at $.10 per square foot.

TABLE A47-2
DATA PROCESSING EQUIPMENT LEASING COSTS
(U. S. Dollars)

Equipment Description	Annual Leasing Cost per Machine (000)	20,000 Units/Year		60,000 Units/Year		90,000 Units/Year	
		Units	Cost (000)	Units	Cost (000)	Units	Cost (000)
Small Computer	$ 30	1	$ 30	1	$ 30	2	$ 60
Medium Computer	130	2	260	2	260	3	330
Large Computer	265	-	-	1	265	1	265
Data Collection Stations	.50	20	10	40	20	75	37
Sorters	.50	6	30	10	50	10	50
Keypunch	.85	25	25	60	55	85	73
Totals			$355		$680		$815

TABLE A47-3

BONUS AND SALARY ADJUSTMENT

(Thousands of U. S. dollars)

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Bonus and Salary Adjustment			
Department			
Foundry	$156.4	$ 395.6	$ 620.0
Stamping	53.9	129.1	275.9
Machining	146.9	379.6	697.0
Assembly	143.9	344.7	503.4
Administration	150.0	200.0	200.0
Materials Handling	41.4	119.6	187.4
Subtotal	$692.5	$1,568.6	$2,483.7
Salary Adjustment (+5%, +10%)	-	78.4	248.3
Adjusted Salary Total	$692.5	$1,647.0	$2,732.0
Bonus @33%	$229.	$ 544.	$ 902.
Salary Adjustment Only			
Office Support	-	$ 865.2	$1,260.2
Factory Support	-	$1,518.6	$2,073.0
Subtotal		$2,383.8	$3,333.2
Salary Adjustment (+5%, +10%)		119.2	333.3
Adjusted Salary Total		$2,503.0	$3,666.5

TABLE A48-1
ADMINISTRATIVE AND SUPPORT PRO FORMA ANNUAL OPERATING COSTS
(Thousands of U. S. dollars)

	20,000 Units/Year	60,000 Units/Year	90,000 Units/Year
Salaries and Fringe Benefit Payments			
Office and Administrative	$1,608	$ 3,304	$ 4,480
Materials Handling	525	1,351	1,938
Factory Support	1,943	5,093	6,902
Subtotal Salary and Fringe Benefits	$4,076	$ 9,748	$13,320
Expenses			
Operating Expenses	$1,280	$ 3,370	$ 4,540
Salary Adjustment	-	197	582
Production and Administrative Bonus	229	544	902
Subtotal Expenses	$1,509	$ 4,111	$ 6,024
Facility Costs			
Depreciation			
Building @5%	$ 108	$ 277	$ 405
Equipment @10%	372	1,042	1,498
Taxes and Insurance @5%	294	798	1,154
Subtotal Facility Costs	$ 774	$ 2,117	$ 3,057
Capital Costs			
Interest on Facilities Investment @7 1/2%	$ 373	$ 999	$ 1,443
Total Operating Costs	$6,732	$16,975	$23,844
Cost per Unit (Actual Dollars)	$ 336	$ 283	$ 265

TABLE A49-1

RECONCILIATION OF TOTAL UNIT COSTS AT DIFFERENT VOLUMES SHOWING COST CHANGES ATTRIBUTABLE TO VOLUME SEPARATELY FROM THOSE ATTRIBUTABLE TO MIX

	20,000- to 60,000-unit volume reconciliation: 60,000-unit volume costs better (worse than) 20,000-unit volume costs				60,000-unit volume constant/actual make-buy mix	60,000- to 90,000-unit volume reconciliation: 90,000-unit volume costs better (worse than) 60,000-unit volume costs				20,000- to 90,000-unit volume reconciliation: 90,000-unit volume costs better (worse than) 20,000-unit volume costs		
	20,000-unit volume actual make-buy mix	Cost change due to increase in number of components fabricated at 60,000-unit volume	20,000-unit volume constant make-buy mix	Cost change due to increase to 60,000-unit volume		Cost change due to increase to 90,000-unit volume	90,000-unit volume constant make-buy mix	Cost change due to increase in number of components fabricated at 90,000-unit volume	90,000-unit volume actual make-buy mix	Cost change due to increase to 90,000-unit volume	Cost change due to increase in number of components fabricated at 90,000 unit volume	Total cost change due to change in volume
VARIABLE COSTS												
Material												
Parts not subject to make-buy decision 1/	$1,519	--	$1,519	$ 99	$1,420	$ 43	$1,377	--	$1,377	$ 142	--	$ 142
Parts subject to make-buy decision 1/	604	(167)	437	29	408	12	396	355	41	41	522	563
Foundry, stamping and machine shop materials 2/	362	50	412	15	397	6	391	(91)	482	21	(141)	(120)
Material	$2,485	$ 117	$2,368	$ 143	$2,225	$ 61	$2,164	$ 264	$1,900	$ 204	$ 381	$ 585
Labour	398	(34)	432	47	385	21	364	(52)	416	68	(86)	(18)
Operating Expenses	145	(8)	153	18	135	2	133	(14)	147	20	(22)	(2)
Support Costs	279	--	279	48	231	16	215	--	215	64	--	64
Variable Costs 2/	$3,307	$ 75	$3,232	$ 256	$2,976	$ 100	$2,876	$ 198	$2,678	$ 356	$ 273	$ 629
FIXED COSTS												
Facilities Cost	$ 395	$ (18)	$ 413	$ 120	$ 293	$ 25	$ 268	$ (29)	$ 297	$ 145	$ (47)	$ 98
Capital Cost	173	(6)	179	36	143	12	131	(15)	146	48	(21)	27
Fixed Costs 2/	$ 568	$ (24)	$ 592	$ 156	$ 436	$ 37	$ 399	$ (44)	$ 443	$ 193	$ (68)	$ 125
PROXY FOR TOTAL UNIT COSTS	$3,875	$ 51	$3,824	$ 412	$3,412	$ 137	$3,275	$ 154	$3,121	$ 549	$ 205	$ 754

1/ Medium horsepower tractor
2/ Average tractor

TABLE A50-1

COMPARATIVE PROFITABILITY OF MANUFACTURING PLANTS AND ASSEMBLY PLANTS AT DIFFERENT VOLUMES

(20,000-UNIT VOLUME)

	Foundry 5/		Stamping Plant to Assembly Plant	Machine Shop to Assembly Plant	Assembly Plant	Adjustments for Profits in Manufacturing Plants 9/	Total Company Position
	1		2	3	4	5	6
	To Machine Shop	To Assembly Plant					
REVENUE -							
Market Selling Price (at 60,000-volume price) of Category of Parts for Medium Horsepower Tractor 1/	$ 449	$ 143	$ 407	$1,490	$4,000		$4,000
Less outside purchased parts 2/	---	---	147	417			
Market Selling Price of Made Parts 3/	$ 449	$ 143	$ 260	$1,073			
		Value of made, finished components Memo: $1,476 - Appendix 2					
Summary Revenues	$ 592		$ 260	$1,073	$4,000 6/		$4,000
VARIABLE COSTS -							
Direct Material Costs							
Raw and Semi-finished Materials							
Foundry raw materials (Table 17)	$ 176						incl.
Sheet steel (for stampings) (App. 14)			$ 74				incl.
Castings (from own foundry) (above)				$ 449		$ 54 7/	$ 54 7/
Forgings (for machine shop) (App. 22)				82			incl.
Steel bars (for machine shop) (App. 22)				9			incl.
Tubing (for machine shop) (App. 22)				15			incl.
Aluminum (for machine shop) (App. 22)				6			incl.
Finished Parts (for assembly) 4/							
Castings					$ 143	17	160
Stampings — Purchased					157	---	157
Stampings — Made					260	(50)	210
Machined parts — Purchased					447	---	447
Machined parts — Made					1,073	(8)	1,065
Standard parts (no make-buy decision)					994	---	994
Purchased assemblies (no make-buy decision)					525	---	525
Total Direct Material Costs	$ 176		$ 74	$ 561	$3,599	$ 13	$3,612
Direct Labour	106		43	159	90	--	90
Operating Expenses	55		13	32	45	--	45
Total Variable Costs -	$ 337		$ 130	$ 752	$3,734	$ 13	$3,747
FIXED COSTS -							
Allocation of Support Costs (Table 39)	99		35	132	70		70
Fixed Costs (Tables 17, 23, 27, 31)	227		45	181	58	---	58
Total Fixed Costs	$ 326		$ 80	$ 313	$ 128	---	$ 128
TOTAL COSTS	$ 663		$ 210	$1,065	$3,862	$ 13	$3,875
ACCOUNTED PROFIT (LOSS)	$ (71)		$ 50	$ 8	$ 138	$ (13)	$ 125
	Divide Foundry ("Loss")						
	$ (54)	$ (17) 8/					

See Notes to Appendix 50, following Table A50-3

TABLE A50-2

COMPARATIVE PROFITABILITY OF MANUFACTURING PLANTS
AND ASSEMBLY PLANTS AT DIFFERENT VOLUMES
(60,000-UNIT VOLUME)

	Foundry 5/		Stamping Plant to Assembly Plant	Machine Shop to Assembly Plant	Assembly Plant	Adjustments for Profits in Manufacturing Plants 9/	Total Company Position
	1		2	3	4	5	6
	To Machine Shop	To Assembly Plant					
REVENUE -							
Market Selling Price (at 60,000 volume price) of Category of Parts for Medium Horsepower tractor 1/	$ 485	$ 143	$ 407	$1,490	$4,000		$4,000
Less outside purchased parts 2/	---	---	145	263			
Market Selling Price of Made Parts 3/	$ 485	$ 143	$ 262	$1,227			
		Value of made, finished components Memo: $1,632 - Appendix 2					
Summary Revenues	$ 628		$ 262	$1,227	$4,000 6/		$4,000
VARIABLE COSTS -							
Direct Material Costs							
Raw and Semi-finished Materials							
Foundry raw materials (Table 17)	$ 182						
Sheet steel (for stampings)(App. 14)			$ 70				
Castings (from own foundry)(above)				$ 485		$ (44) 7/	$ (44) 7/
Forgings (for machine shop)(App. 22)				105			
Steel bars (for machine shop)(App. 22)				12			
Tubing (for machine shop)(App. 22)				20			
Aluminum (for machine shop)(App. 22)				8			
Finished Parts (for assembly) 4/							
Castings					$ 143	(13)	130
Stampings — Purchased					145	---	145
Stampings — Made					262	(101)	161
Machined parts — Purchased					263	---	263
Machined parts — Made					1,227	(117)	1,110
Standard parts (no make-buy decision)					929	---	929
Purchased assemblies (no make-buy decision)					491	---	491
Total Direct Material Costs	$ 182		$ 70	$ 630	$3,460	$ (275)	$3,185
Direct Labour	100		33	170	82		82
Operating Expenses	52		10	32	41		41
Total Variable Costs	$ 334		$ 113	$ 832	$3,583	$ (275)	$3,308
FIXED COSTS -							
Allocation of Support Costs (Table 39)	81		23	123	56		56
Fixed Costs (Tables 17, 23, 27, 31)	156		25	155	48		48
Total Fixed Costs	$ 237		$ 48	$ 278	$ 104		104
TOTAL COSTS	$ 571		$ 161	$1,110	$3,687	$ (275)	$3,412
ACCOUNTED PROFIT (LOSS)	$ 57		$ 101	$ 117	$ 313	$ 275	$ 588
Divide Foundry ("Loss")	$ 44	$ 13 8/					

See Notes to Appendix 50, following Table A50-3

TABLE A50-3

COMPARATIVE PROFITABILITY OF MANUFACTURING PLANTS

AND ASSEMBLY PLANTS AT DIFFERENT VOLUMES

(90,000-UNIT VOLUME)

	Foundry 5/		Stamping Plant to Assembly Plant	Machine Shop to Assembly Plant	Assembly Plant	Adjustments for Profits in Manufacturing Plants 9/	Total Company Position
	1		2	3	4	5	6
	To Machine Shop	To Assembly Plant					
REVENUE -							
Market Selling Price (at 60,000-volume price) of Category of Parts for Medium Horsepower Tractor 1/	$ 548	$ 143	$ 407	$1,490	$4,000		$4,000
Less outside purchased parts 2/	---	---	10	32			
Market Selling Price of Made Parts 3/	$ 548	$ 143	$ 397	$1,458			
		Value of made, finished components Memo: $1,998 - Appendix 2					
Summary Revenues	$ 691		$ 397	$1,458	$4,000 6/		$4,000
VARIABLE COSTS -							
Direct Material Costs							
Raw and Semi-finished Materials							
Foundry raw materials (Table 17)	$ 185						
Sheet steel (for stampings)(App. 14)			$ 103				
Castings (from own foundry)(above)				$ 548		$ (103) 7/	$ (103) 7/
Forgings (for machine shop)(App. 22)				141			
Steel bars (for machine shop)(App. 22)				16			
Tubing (for machine shop)(App. 22)				26			
Aluminum (for machine shop)(App. 22)				11			
Finished Parts (for assembly) 4/							
Castings					$ 143	(27)	116
Stampings (Purchased					10	--	10
Stampings (Made					397	(184)	213
Machined parts (Purchased					31	---	31
Machined parts (Made					1,458	(190)	1,268
Standard parts (no make-buy					901		901
Purchased assemblies (decision					476		476
Total Direct Material Costs	$ 185		$ 103	$ 642	$3,416	$ (504)	$2,912
Direct Labour	105		45	186	80		80
Operating Expenses	52		13	41	41		41
Total Variable Costs	$ 342		$ 161	$ 969	$3,537	$ (504)	$3,033
FIXED COSTS -							
Allocation of Support Costs (Table 39)	73		26	119	47		47
Fixed Costs (Tables 17, 23, 27, 31)	146		26	180	41		41
Total Fixed Costs	$ 219		$ 52	$ 299	$ 88	---	$ 88
TOTAL COSTS	$ 561		$ 213	$1,268	$3,625	$ (504)	$3,121
ACCOUNTED PROFIT (LOSS)	$ 130		$ 184	$ 190	$ 375	$ 504	$ 879
	Divide Foundry ("Loss")						
	$ 103	$ 27 8/					

See Notes to Appendix 50, following Table A50-3

NOTES TO APPENDIX 50

General Note: Appendices A50-1, A50-2, and A50-3 re-analyze the costs of the three tractor plants producing at the three different volume levels on the basis that the products of each have the same market value. What will be the cost savings at higher volumes, and in which plant will they occur to which extent? Since, given a constant selling price, cost differentials are profit differentials, what profits will be earned (beyond the 7.5% market cost of capital) by each plant at each volume? From these data and other information in the study, return-on-investment percentages can be calculated.

1/ The "Market Selling Prices" shown in this line are taken from the values shown in the column "All Components" of Table A2-2. They are therefore the prices for the purchase of these items at the 60,000-unit volume level, and are not adjusted to show the cost penalty of 7% anticipated for purchases at the 20,000-unit volume level or the cost savings of 3% at the 90,000-unit volume level. For foundry data, see Note 5.

The assumed separate manufacturing plant revenues are therefore based on what the 60,000-unit volume manufacturer would be expected to pay for the parts manufactured, and allow then a comparison of profit levels to be made for the different plants at different volumes.

2/ The weighted average price of the tractors is taken from Table 44. The value of "Outside Purchased Parts" is taken from the appropriate 20,000-, 60,000-, and 90,000-unit volume "Buy Items" columns of Table A2-2, and therefore represents the cost of these parts for the medium horsepower tractor only.

3/ The "Market Selling Price of Made Parts" is therefore the price of the parts made in the foundry, stamping plant and machine shop to a manufacturer of 60,000 tractors a year, again on the basis of the costs of these parts for the medium horsepower tractor.

4/ Finished Parts (for Assembly): The prices shown under the column "Assembly Plant" are a combination of the values of the parts made from line 3 and the purchase price of the parts bought outside, at the price appropriate to the volume level in question. The price of the parts purchased therefore includes the 7% penalty cost identified in Table A2-3 anticipated at the 20,000-unit volume level and the cost saving of 3% at the 90,000-unit volume.

5/ Calculation of foundry market prices was made by marking up foundry costs (Table 17) of cast parts requiring machining by 10% with the constant group of cast parts not requiring machining shown as the constant value of $143 (at 60,000 volume) from Appendix 1. By using foundry costs from Table 17, the foundry is allowed presumed 10% profits on the lower-volume, higher cost production, rather than holding market values constant. This will have the effect of transferring profits to foundry at the 20,000-unit volume which should be earned in the machine shop and reducing profits in the foundry at 90,000-unit volume. Calculation is as follows:

Step 1. Calculation of outside purchase price of castings requiring machining at 60, 000-unit volume.

Foundry cost for parts requiring machining (Table 17)	$441
Add 10% for profit (see note to Table 17).	44
	$485

Step 2. Calculation of value of outside purchase price of castings requiring machining at 60, 000-unit volume.

	Value	% of castings
Value of all castings at 60, 000-unit price (Appendix 2)	$1, 095	100
Value of castings made at 60, 000-unit volume at 60, 000-unit price $1, 095 - $126 =	969	88.5
Value of castings made at 20, 000-unit volume at 60, 000-unit price $1, 095 - $197 =	898	82.0

If $485 = 88.5% of castings,
then $548 = 100% of castings,
and $449 = 82% of castings.

6/ The amount $4, 000 is derived from Table 44.

7/ It is necessary to deduct the "profit" or add the "loss" recorded against the foundry castings transferred to the machine shop for further work. This amount does not show up in the "profit" of the machine shop.

8/ Foundry "profit" or "loss" is here allocated proportionally between the foundry castings which go directly to the machine shop and those not requiring machining which go to the assembly plant directly, on same basis as Table 17.

9/ Column 5 should be read with the following in mind: Above double line, numbers without parentheses represent plant losses or cost increases; numbers in parentheses represent plant profits, or cost decreases. Below double line, situation is reversed, numbers in parentheses representing losses, those without parentheses representing profits.

TABLE A51-1

CALCULATIONS OF COSTS OF DIFFERENT TRACTOR MODELS
AND WEIGHTED AVERAGE COSTS OF TRACTORS
(at 60,000-unit volume)

1. CALCULATIONS OF COSTS OF DIFFERENT TRACTOR MODELS	Low HP Model (35-45 HP)	Medium HP Model (80-100 HP)	High HP Model (125-135 HP)
PURCHASED COMPONENTS			
Purchased Standard Parts			
Items Affected by Specification Change Only (Tires & Battery)	$ 265	$ 600	$ 790
Items Affected by Both Specification and Volume Change	280	329	445
Purchased Assemblies	470	491	665
Components Subject to Make-Buy Decision Purchased at this Volume			
Castings	95	126	160
Forgings	50	61	70
Stampings	128	145	170
Steel Bars	30	32	45
Tubing	38	42	53
Aluminum	2	2	2
Total Purchased Components	$1,358	$1,828	$2,400
MANUFACTURED COMPONENTS			
Foundry Costs Per Unit			
Tons of Castings	1.25	2.5	4.3
Cost Per Ton[1/]	$ 248	$ 248	$ 248
Total Costs Per Unit	$ 309	$ 620	$1,066
Stamping Plant Costs Per Unit			
Material	57 (-25%)	76	(+10%) 84
Labour	31 (+ 5%)	30	(+25%) 37
Expenses	9 (-10%)	10	(+20%) 12
Fixed Costs	25 (+ 5%)	24	(+15%) 28
Support Costs	23	23	23
Total Stamping Plant Costs Per Unit	$ 145	$ 163	$ 184
Machining Costs Per Unit			
Materials Other Than Castings			
Forgings	103	103	136
Aluminum	6	8	10
Steel Bars	8	12	14
Tubing	17	20	24
	$ 134	$ 143	$ 184
Machining Costs Other Than Materials			
Labour	153 (-10%)	170	(+30%) 221
Expenses	30 (- 5%)	32	(+10%) 35
Fixed Costs	140 (-10%)	155	(+30%) 201
Support Costs	123	123	123
	$ 446	$ 480	$ 580
Total Machining Costs Per Unit	$ 580	$ 623	$ 764

TABLE A51-1 (Concluded)

	Low HP Model (35-45 HP)	Medium HP Model (80-100 HP)	High HP Model (125-135 HP)
ASSEMBLY OPERATIONS			
Labour	72 (-15%)	85	(+25%) 106
Expenses	39 (- 5%)	41	(+10%) 45
Fixed Costs	42 (-15%)	49	(+25%) 61
Support Costs	56	56	56
Total Assembly Costs per Unit	$ 209	$ 231	$ 268
TOTAL COSTS OF TRACTOR	$2,601 2/	$3,465	$4,682

2. CALCULATION OF WEIGHTED AVERAGE COSTS OF TRACTORS

	Low HP	Medium HP	High HP
Percentage of Total Production Represented by Model Group in Plant Mix	30%	60%	10%
Weighted Cost of Model Group	/ $780	$2,079	$468 /
Average Cost of Tractors		$3,327	

1/ Cost per ton calculated from $571 total foundry costs per unit divided by 2.3 tons per average unit, equalling $248 per ton.

2/ Based on diesel engine. Gasoline engine would reduce per unit cost about $200 in this horsepower size.

TABLE A52-1

CALCULATIONS OF THE EFFECT OF VOLUME FLUCTUATIONS ON COST

Material: No Change

Labour:

At 20% less:
1. Add 10% of direct labour for SUB. Anticipated weekly payment equals about half normal earnings.
2. Add 15% of indirect labour for SUB and underutilized personnel. Assume only half indirect personnel could be laid off. SUB would equal about half wages of those laid off.
3. Add 20% to fringe benefit costs on the basis that most fringe costs are "per head" rather than "per hour".

At 20% more:
1. Add 8.3% of direct labour for overtime premium on 20% more hours.
   $\frac{1 + (.20 \times 1\ 1/2)\ \text{dollars}}{1.20\ \text{units}} = 1.083$ per unit.
2. Add 62% of indirect labour for overtime premium on 15% more hours.
3. Reduce fringe benefit cost by 16.7% to allocate basically fixed cost over 20% more production.

	-20%	20,000 Units/Year	+20%	-20%	60,000 Units/Year	+20%	-20%	90,000 Units/Year	+20%
	(U.S. dollars)								
Foundry									
Direct Labour	$ 61	$ 56	$ 61	$ 63	$ 57	$ 62	$ 66	$ 60	$ 65
Indirect Labour	30	26	28	23	20	21	24	21	22
Fringe Benefits	29	24	20	28	23	19	29	24	20
Subtotal	$120	$106	$109	$114	$100	$102	$119	$105	$107
Stamping									
Direct Labour	$ 30	$ 27	$ 29	$ 24	$ 22	$ 24	$ 33	$ 30	$ 33
Indirect Labour	7	6	6	5	4	4	6	5	5
Fringe Benefits	12	10	8	8	7	6	12	10	8
Subtotal	$ 49	$ 43	$ 43	$ 37	$ 33	$ 34	$ 51	$ 45	$ 46
Machining									
Direct Labour	$119	$108	$117	$130	$118	$128	$140	$127	$137
Indirect Labour	16	14	15	15	13	14	18	16	17
Fringe Benefits	44	37	31	47	39	32	52	43	36
Subtotal	$179	$159	$163	$192	$170	$174	$210	$186	$190
Assembly									
Direct Labour	$ 65	$ 59	$ 64	$ 60	$ 54	$ 58	$ 58	$ 53	$ 57
Indirect Labour	12	10	11	10	9	10	10	9	10
Fringe Benefits	24	21	17	23	19	16	22	18	15
Subtotal	$101	$ 90	$ 92	$ 93	$ 82	$ 84	$ 90	$ 80	$ 82
Total Labour	$449	$398	$407	$436	$385	$394	$470	$416	$425

Operating Expenses:

At 20% less:
Increase cost by 19% on the basis that operating expenses are 75% fixed in short run. $\frac{\$1.00 - (.20\ \text{reduction} \times .75\ \text{degree fixed})}{\text{units}\ 1.00 - .20\ \text{reduction}} = 1.19$

At 20% more:
Decrease cost by 12% on same basis. $\frac{\$1.00 + (.20\ \text{increase} \times .25\ \text{variable})}{\text{units}\ 1.00 + .20\ \text{increase}} = .88$

Administrative and Support, Facility and Capital Costs:

At 20% less:
Increase cost by 25% since same costs are to be allocated to 80% of planned production.

At 20% more:
Decrease cost by 16.7% since same costs are to be allocated to 120% of planned production.