A PRODUCTIVITY MEASUREMENT SYSTEM FOR MANUFACTURING PLANTS

by

Wen-Chieh Shu

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APPROVED:

P. M. Ghare, Chairman

M. H. Agee

W. J. Fabrycky

E. L. Hirschhorn

W. E. Leininger

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Blacksburg, Virginia

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TABLE OF CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

I. BACKGROUND OF PRODUCTIVITY PROBLEM

1-1. What is Productivity?

Productivity is a measure of economy of means [60]. The word "means" refers to an activity or a resource which changes the value of goods and services. The means which increase the value of goods and services are called productive, and the ones which decrease the value of goods and services are called counter-productive. It must be remembered that productivity is not the only measure of the economy of means. An example of alternative measures is profitability.

There are two types of productivity: physical productivity and economic productivity. The physical productivity refers to the ratio of output and input, expressed in the physical terms. The ratio of tons of steel produced to the number of employees is physical productivity. Economic productivity is also a ratio of output and input, but expressed in the forms of economic value. Profitability is economic productivity.

Productivity has two measuring facets: absolute productivity tells the level of productivity; productivity growth shows the rate of productivity change from one period to another. The absolute productivity represents standard of living [53]; productivity growth represents the strength of competition as well as the improvement in standard of living. The living standard in the U.S. remains at the top of the industrialized countries because the U.S. absolute productivity is still the highest [2, 17, 28]. However, the American competitive position in international trade markets has become weaker due to its productivity growth.

Although productivity is one of the most widely used terms, people interpret productivity subjectively. The subjectivity is because of the different value systems which people have and the difficulty of obtaining measure of productivity acceptable to all.

1-2. Terminology and Definitions.

In a simple mathematical form, productivity is defined as the value ratio of output to input of a production system. The higher the ratio, the more productive is the system.

When total output and total input are used, the ratio is total productivity. For instance, the total productivity of a plant may take all products produced as the total output and the sum of labor, capital, material, energy, building, and land as the total input. The ratio obtained by dividing the total output by one or some of the inputs is partial productivity. An example of partial productivity is labor productivity which uses labor as the only input. Capital productivity, material productivity, etc. can also be defined in the same manner. If materials are excluded in both the total output and total input, the ratio is called total factor productivity. Another form of the total factor productivity is using the value added as the output and the sum of labor and capital as the input. For all the productivity ratios, output is the result of the input transformation. Any output which is not generated by the input factors, is not the true output and should be excluded in the productivity ratio.

1-3. Hierachy of Production Systems.

The hierachy of production systems refers to economic levels, or magnitudes of production systems. Since productivity is a study of production system, the production system involved has to first be identified. The principal economic levels are nation, major industry, industrial sector, corporation, plant, department, work station, and individual resources.

For the national productivity of the U.S., the Bureau of Labor Statistics (BLS), Department of Labor, collects the data for the labor productivity and identifies the causes of productivity trends. The BLS also compiles the labor productivity for major industries such as automobile, steel, etc.

1-4. Productivity as a Management Cycle.

Productivity has three basic functions: measurement, analysis, and improvement. Sumanth [55] further classified these activities into measurement, analysis, evaluation, and improvement. The contention of such classifications is to identify productivity with management as a planning, execution, and evaluation cycle.

Productivity measurement results in various productivity indexes. Productivity analysis identifies the causes of productivity changes and projects future productivity trends. Productivity improvement is the implementation of solutions identified by the productivity analysis.

Productivity measurement can be an independent function from the other two productivity activities because its objective is solely to show how the system performs.

1-5. Use of Productivity Information.

Productivity information is primarily used in the form of comparisons. Comparisons of productivity can be made with multiple production systems at one time period, or for the same production system at multiple time periods. Examples of the former and latter use are international productivity and productivity growth. Comparisons are commonly made for the production systems which are in the same economic level and have similar production characteristics.

Because the interest of this study is in manufacturing systems, the use of organizational productivity deserves special attention. Seven common usages of organizational productivity information are: (1) to monitor and control of production system; (2) for managerial performance appraisal and motivation; (3) for short-to-medium range planning; (4) for standard, and price setting; (5) for long-range planning; (6) for labor negotiation and compensations; (7) to inform and influence outsiders. Chapter IV will present the use of productivity information for the monitoring and control purposes.

II. PROBLEMS OF PRODUCTIVITY MEASUREMENT (PM) AND OVERVIEW OF THIS STUDY

2-1. Problems of Productivity Measurement.

Productivity measurement (PM), which is an important activity in the productivity program, is the subject of this study. The term "productivity" is defined as the output-input ratio as in Chapter I. Although the ratio is simple, PM becomes complex because both input and output are difficult to measure. The following five problems of PM are commonly encountered. This list is not exhaustive; but does cover the principal problems.

2-1-1. Tangibility of Inputs and Outputs.

Tangible economic factors are those that can be quantified and measured. Only tangible inputs and outputs are used in the PM. Although the productivity theory does not require that factors be tangible, the tangibility makes the measurement realistic. Since a production system involves both internal (to the system) and external factors, many of these being uncertain, intangible factors are always present. Intangibility is inherent to many production systems, especially when the cause-effect relationships of the production process are being studied. Some factors, tangible by definition, may become intangible because the cost of data collection is too high. As technologies and measuring techniques advance, the previously intangible factors may become tangible. Techniques such as Nominal Group Technique or Regression Analysis are often used in reducing the personal biases and therefore the intangibility.

2-1-2. Measuring Units.

The measuring unit used in PM is the value of the input and output. If values for goods and services are not difficult to obtain, the measuring unit does not constitute a problem of PM. Unfortunately, value is subjective and the same commodity may be valued differently by different people. Even for a piece of equipment, there are differing ways of representing its value, such as Historical Cost, Current Replacement Cost, Net Realizable Value, Net Present Value of Expected Future Cash Flows, Current Cost, or Recoverable Amount.

For a system producing multiple products, PM depends on the feasibility of obtaining common units of measure. This applies to the inputs although the measuring unit for the inputs need not be the same as that for the outputs. Depending upon the characteristics of production systems, different measuring units may be selected for different applications. In practice, the most commonly used measuring units are price, cost, and time.

Because of its wide adoption, market price as the measuring unit deserves special attention. As indicated in Chapter I, productivity represents efficiency. The fluctuations of market prices can affect the financial performance but may have no impact on the production efficiency. Since the market price fluctuations are generally extraneous, the productivity measures using the market prices for the inputs and outputs can provide biased information. Production time appears to be free from the price effect, but is subject to fluctuations of different input values. For example, input in labor hours has to include different labor categories which represent different wages and skill levels. Adding 8 hours of a foreman's work to 8 hours of a lathe operator's contribution requires the transformation of the foreman's time into the lathe operator's time, or vice versa. Wage, in essence, can be regarded as the market price of employees. To eliminate the effect of price fluctuations, deflating or inflating schemes are necessary. However, deflating or inflating requires the determination of a base period for the subsequent productivity measurements.

2-1-3. Base Period Selection.

As it was stated in Chapter I, the primary usage of productivity is for comparisons. The current productivity of a firm, for instance, may be compared to that in past periods, to the planned productivity, to the productivity of its competitors, or to the average for the industry. In all these comparisons, the same measuring criteria and the same base period are necessary. One example of base period selection is the U.S. Consumer Price Index (CPI) which takes the year 1967 as the basis; i.e., CPI is 100 for the year 1967. The productivities of subsequent periods are then compared to that of the base period. The base period may be changed for various reasons, such as change of product mix, change of product cost etc. Once a base period is chosen, the price effect can be largely eliminated by using the base prices for the current period, and the residual bias is relatively minor especially when the base period is a stable one.

2-1-4. Incorporating Quality into Value Measures.

While quality of production in the PM can be an independent topic as the quality productivity, the common approach in the PM implicitly assumes that the product quality is reflected in the market price, i.e., high quality product gets high market price. Usually a better quality product means higher product value, but not necessarily a higher market price. Modifications of the existing product, such as addition of new features to the old product, or use of improved quality materials, all tend to improve the product quality. In practice, the improved products may be treated the same as their predecessors unless the market prices change. To some extent, these quality changes can accumulate to make the product totally different from the one evaluated at the base period. In such a case, re-evaluation of the value of improved product at the base period is necessary. Another approach of incorporating quality into the value measure is using the subjectively assessed value. The survey type of assessment, such as Delphi Technique, may be needed to obtain a commonly accepted value measure.

2-1-5. Time Lag in Productivity Information.

Time lag in PM arises from three causes: the difficulty in identifying the causal effect of output and input, the uncertainty in data transmission, and the lead time between the output and input. For a fast production system, lead time represents no problem since PM requires time duration to aggregate the output. However, when production pace is slow and lead time is lengthy, productivity can be measured only after a certain time period has elapsed.

To understand the nature of time lag, it is necessary to recognize the causal relationships between economic factors. Productivity growth, for example, is believed to be affected by three major factors: technological change, capital investment, and scale of economy. One important source of the technological advancement is through Research and Development (R & D). In general, fundamental R & D activities are time consuming and the results are hard to predict. Because of the time lag and longevity of R & D contributions, the productivity at a certain period may be due to the cumulated R & D efforts made at many previous periods. In such case, productivity measurement provides biased information because the current output is not solely resulted from the current input.

2-2. Overview of this Study.

This study deals with productivity measurement at the plant level. The choice of plant level comes from three main considerations. First, when the economic level is that of a firm, financial considerations such as capital availability become important or even dominate. Further, there are government agencies designated to compile productivity indexes at industrial and national levels. The second consideration is that a majority of the literature in PM has been at the macro economic levels, i.e., national and industry levels. It is only recently that the importance of productivity at the micro economic levels has been realized. The third consideration is that the plant level and lower levels are the basic operating units where engineering technique may be profitably applied to improve productivity. The corporate, industry, and national economy are the aggregate of these micro operating units.

While productivity improvement may be of primary interest in a plant, this improvement can only be recognized when the productivity is measured. There are two types of PM: direct measurement and indirect measurement. The direct measurement uses actual quantities of input and output. Otherwise, the measurement is indirect. This study uses direct measurement.

In addition to the direct measurement, PM in this study excludes the considerations of external factors; usually refered to as the environment of production. An example of such external factors can be "maximum output of production unit K". As the external factors are excluded, the boundary of the production system is limited to the physical production itself. In technical terms, PM in this study is called process productivity since it deals with the production process only. The other PMs are "expected productivity" and "global productivity" which involve external factors to varying degrees [38].

In this sense, the interest of this study is the direct measurement of process productivity at the manufacturing plant. Starting with the literature survey and identifying the potential new work, the following objectives are set out for this study:

(i) development of an appropriate model for PM at the manufacturing plant level.

(ii) investigation of integrating the developed PM model in management reporting.

(iii) development of an in-plant productivity monitoring system.

(iv) a real-world case study to demonstrate the developed system.

III. HISTORIAL DEVELOPMENT - A LITERATURE SURVEY

The literature on productivity measurement is diverse and covers numerous evaluation problems which range from productivity evaluation of a single worker to measuring productivity of a nation. Because of the interests of this study, the literature survey is limited to the productivity measurements at the plant level and below. In some cases, the plant level may coincide with the corporate level. However, multi-plant or multi-division corporate level productivity measurement is outside the scope of this study. Moreover, in order to illustrate the direct and indirect productivity measurements recognized by this study, six direct measuring models are described in Section 3-1 and three indirect ones in Section 3-2. Other concepts, which are related to but are not the productivity measurement models, are presented in Section 3-3.

3-1. Direct Measurement Models.

Kendrick and Creamer [30] presented the first model of direct productivity measurement at the company level. The production output used in their model was the adjusted net sales; the adjustments were made according to the differences in the semifinished and finished goods at the beginning and ending periods of measurement. As incomes from portfolio holdings of stocks and bonds did not result from the production, they were not included in the output. Input categories were labor, material, services, and capital; but only output-related inputs were included in the productivity calculations. Price and cost deflators were applied to both the outputs and inputs to obtain their value at base period. The model applied total, total factor, and partial productivities to six participating companies.

The second model of productivity measurement is Craig and Harris's [10] Service Flow Model (SFM) which applied total and partial productivities to a manufacturing firm. Production inputs of SFM included labor, capital, raw materials and purchased parts, and other miscellaneous goods and services. Production output was the firm's net production. Each of these inputs and output was defined by its scope and components. To measure productivities, a base year was selected and the weight of each of the inputs and output was taken from either its actual or estimated base year value. The SFM has a special treatment for the capital inputs. Instead of using depreciation from the accounting records or weighted labor hours, a measure called 'value of capital' was used. In other words, the SFM assumed that a leasing subsidiary firm provided the necessary capital inputs, such as land, building, equipment, and current assets. To use these capital inputs, the company had to pay to this subsidiary. Annual leasing cost was determined by the initial cost and production life of the asset, and the desired rate of return to the subsidiary. Cash, accounts receivable, inventory, and other liquid assets were assumed to have zero productive life. Selling price at base year was used as the weight for all inputs and outputs. For those that did not exist at the base year, the value deflators were also compiled.

The third model was the Omni-Factor Model (OFM) proposed by Smith [50]. In terms of its components, the total input used in the OFM included five cost categories: (1) raw material costs (includes purchase, transportation and warehousing, interest on money invested, and loss on waste); (2) personnel costs (includes wages, bonus payments, fringe benefits, and other labor charges); (3) capital costs (includes interest on capital invested, depreciation, and stock investment costs); (4) indirect production costs (includes maintenance, indirect wages and salaries); (5) purchase for production (includes power and lights, heat, compressed air, raw materials, and stored items). The total output adopted by the OFM is a weighted sum of output products. A simplified mathematical model of OFM is shown below.

There are n products and product i is the major product. For product j, the input cost and quantity produced at period t are C_{jt} and Q_{jt}, and

$$C_{jt} = \sum_{k} C_{kjt}, \text{ k is the cost category}$$

and the average marginal cost of product j at period t is AMC_{jt};

$$AMC_{jt} = C_{jt}/Q_{jt}$$

Thus, the weight of product j is W_{jt};

$$W_{jt} = AMC_{jt}/AMC_{it}$$

and the total output is O_t;

$$O_t = \sum_{j=1}^{n} Q_{jt} W_{jt}$$

The level of productivity at period t is L_t;

$$L_t = O_t / \sum_{j=1}^{n} C_{jt}$$

If t=0 is taken as the base period, the total productivity index at period t is P_t;

$$P_t = (L_t/L_o) \times 100\%$$

The fourth model of direct productivity measurement is the EGS model developed by Eilon, Gold and Soesan [14]. In the EGS model, various indexes including capacity utilization, fixed investment utilization, physical output, total and partial productivities are used as production measures. The EGS model is based on Edgeworth's approach (Edgeworth, F. Y., "The plurality of index numbers", Economic Journal, Vol. 35, pp. 379-88). which treats the physical output as the total product value, and further applies to the inputs. There are four production inputs: labor, capital, materials, and other financially tangible inputs. Instead of measuring the absolute productivities, productivity growth is obtained from the changes of weighted physical inputs and outputs. In doing so, at least two time periods are needed; one is preferred to be the base period. The model shown below assumes two products at two time periods.

There are two products i and j, and two time periods t and s.

Q_{jt} is the quantity of product j at time t

P_{jt} is the price of product j at time period t

D_{ks} is the quantity of input factor k at time s

C_{ks} is the cost of input factor k at time s

The change of weighted physical output from t to s is PO_{ts};

$$PO_{ts} = (Q_{is} \times P_i + Q_{js} \times P_j) \;/\; (Q_{it} \times P_i + Q_{jt} \times P_j)$$

where, $\quad P_i = 0.5 \times (P_{it} + P_{is})$ and $P_j = 0.5 \times (P_{jt} + P_{js})$

The change of weighted physical input from t to s is PI_{ts};

$$PI_{ts} = \left(\sum_{k=1}^{4} D_{ks} \times C_k \right) / \left(\sum_{k=1}^{4} D_{kt} \times C_k \right)$$

where, $C_k = 0.5 \times (C_{kt} + C_{ks})$

And, the productivity change from t to s is PG_{ts};

$$PG_{ts} = PO_{ts} / PI_{ts}$$

In the above calculations, different methods, such as the following Fisher's Ideal Index method (The Making of Index Numbers, Hougton Mifflin Co., New York), may be used to calculate the change of weighted physical output.

$$PO_{ts} = \{[(Q_{is} \times P_{it} + Q_{js} \times P_{jt}) / (Q_{it} \times P_{it} + Q_{js} \times P_{jt})] \times [(Q_{is} \times P_{is} + Q_{js} \times P_{js}) / (Q_{it} \times P_{is} + Q_{jt} \times P_{js})]\}^{1/2}$$

The fifth model of direct productivity measurement is the APC model, developed by the American Productivity Center [2], Houston, Texas. The measures developed in the APC model include three indexes - productivity, pricing recovery, and cost effectiveness indexes, and also the variances of these three indexes. The APC model compares these performance indexes at any two operating periods. However, a base period is still used for the convenience of the model presentation. Three principal indexes and their variances are described below. The inputs of the APC model are labor, capital, materials, energy, and other miscellaneous inputs. The production outputs are the physical products. The following four sub-sections, (i) to (iv) illustrate three indexes and variances of the APC model.

(i) Productivity Index (P).

This index is the quantity ratio of current period to base period. The quantities are price-weighted.

$$\text{Productivity Index (P)} = \left(\sum_{O} Q_2^{O} P_1^{O} \Big/ \sum_{O} Q_1^{O} P_1^{O}\right) \Big/ \left(\sum_{I} Q_2^{I} P_1^{I} \Big/ \sum_{I} Q_1^{I} P_1^{I}\right)$$

where 2 is current period, 1 is base period, O is output, I is input, Q is quantity, P is price. Thus Q_2^{O} is the quantity of a output product at current period. $\sum_{O}$ is the summation for all output products, $\sum_{I}$ is the summation for all production inputs.

(ii) Pricing Recovery Index (R).

This index is the price ratio of current period to base period. The prices are quantity-weighted.

$$\text{Pricing Recovery (R)} = \left(\sum_{O} Q_2^{O} P_2^{O} \Big/ \sum_{O} Q_2^{O} P_1^{O}\right) \Big/ \left(\sum_{I} Q_2^{I} P_2^{I} \Big/ \sum_{I} Q_2^{I} P_1^{I}\right)$$

(iii) Cost Effectiveness Index (E).

This index is the value ratio of outputs and inputs at two time periods. It reflects how production costs and production value of the current period are relative to those of the base period.

$$\text{Cost Effectiveness (E)} = \left(\sum_{O} Q_2^{O} P_2^{O} \Big/ \sum_{O} Q_1^{O} P_1^{O}\right) \Big/ \left(\sum_{I} Q_2^{I} P_2^{I} \Big/ \sum_{I} Q_1^{I} P_1^{I}\right)$$

The relationship between the Productivity Index (P), Pricing Recovery Index (R), and Cost Effectivensss Index (E) is

$$E = P \times R$$

In addition to total productivity, partial productivities, such as labor, material, capital, energy, and services productivities, can be computed in the same manner.

(iv) Variances.

Cost Effectiveness Variance (C1) is the difference between the change in the value of the products and the change in the value of the inputs. It gives the initial indication of contribution of each input to the attainment of overall goal of the company.

$$C1 = \sum_{I} Q_1^I P_1^I \left[\left(\sum_{O} Q_2^O P_2^O / \sum_{O} Q_1^O P_1^O \right) - \left(\sum_{I} Q_2^I P_2^I / \sum_{I} Q_1^I P_1^I \right) \right]$$

Productivity Variance (C2) is the difference between the change in the quantity of the product and the change in the price of the inputs. It shows to what extent any input has contributed to the efficiency of the firm's attempt to obtain its goals.

$$C2 = \left(\sum_{I} Q_1^I P_1^I \right) \left[\left(\sum_{O} Q_2^O P_1^O / \sum_{O} Q_1^O P_1^O \right) - \left(\sum_{I} Q_2^I P_1^I / \sum_{I} Q_1^I P_1^I \right) \right]$$

Pricing Recovery Variance (C3) is the difference between the change in the price of the product and the change in the price of the inputs. It shows to what extent the firm has been able to absorb the increases in prices of inputs.

$$C3 = C1 - C2$$

The sixth model of direct productivity measurement is the Product-Oriented Model (POM), developed by Sumanth [55]. The POM is called product-oriented because it provides the total productivity indexes for each product or product group. The production outputs of the POM include finished units produced, partial units produced, dividends from securities, interest from bonds, and other income; all outputs generated through the firm's efforts are included. Five production inputs of the POM are labor, capital, material, energy, and other expenses. Both direct and indirect manpower are included in the labor input. The capital input consists of fixed and working capital. The material input includes raw materials and purchased parts. The energy input includes gas, electricity, etc., and other expenses include taxes, marketing, R & D, and general administrative expenses. Mathematically, the POM is shown as follows:

$$TPF = \sum_{i=1}^{N} O_i \Big/ \sum_{i=1}^{N} I_i = \sum_{i=1}^{N} O_i \Big/ \sum_{i=1}^{N} \sum_{j=1}^{5} I_{ij}$$

where,

TPF = total productivity of a firm

O_i = output of product i

I_{ij} = input factor j corresponding to product i

N = number of products manufactured.

The total productivity index of the firm at time t, relative to time 0, is $(TPF)_t$;

$$(TPF)_t = TPF_t \,/\, TPF_0$$

where, TPF_t = total Productivity of the firm at time t.

TPF_0 = total Productivity of the firm at time 0.

Total Productivity Index for product i at time t, relative to time 0, is $(TPI)_{it}$;

$$(TPI)_{it} = TP_{it} \; / \; TP_{i0}$$

where,

$$TP_{it} = O_{it} \; / \; \sum_{j=1}^{5} I_{ijt}, \qquad TP_{i0} = O_{i0} \; / \; \sum_{j=1}^{5} I_{ij0}$$

and, O_{it} = output of product i at time t.

I_{ijt} = input factor j corrsponding to product i at time t.

TP_{it} = total productivity of product i at time t.

In addition to the above total productivities, the POM measured the firm's profit (PF) in terms of the TPF (total productivity of the firm);

$$PF = OF - IF + I_{wc} = (TPF - 1) * IF + I_{wc}$$

where, OF, IF, and I_{wc} are the total output, total input, and working capital of the firm.

3-2. Indirect Measurement Models.

The first indirect productivity measurement model at the plant level was constructed by Ernst [15] using the production function theory. By taking the logarithmic transformation of net production function, an additive production function can be obtained as follows:

$$\text{Total Output (y)} = C + \sum_{i} K_i X_i$$

where C is a constant, X_i is the input factor i, and K_i is coefficient of X_i. To determine the input factors, a co-relational analysis between the inputs and output was exercised. Furthermore, a regression model, linear or nonlinear, was applied to estimate the coefficients K_i and constant C. It is also noted that since the production function is a causal model, the input resources can be physical measures such as tons, yards, or cubic inches. In this regard, Ernst hypothesized a strong correlation between technological changes and energy consumption. That is, the technological and capital inputs can be correlated with energy inputs.

The second indirect PM model, which deals with worker productivity is the System Dynamic Model (SDM) developed by Hersauer and Ruch [23]. The SDM is based on the interrelated relationships between individuals, the organization, and external factors. A large number of social and psychological factors affecting the worker performance are included. In addition to using a subsystem approach, Hersauer and Ruch followed the procedures listed below and applied them to a participating company.

(i) Two types of factors, individually controlled factors and organizationally controlled factors, are distinguished.

(ii) Control rates are determined for all control factors.

(iii) Long-term factors are distinguished from short-term factors

(iv) Time is an implicit factor; but it becomes an explicit factor when time delay is introduced.

(v) The relationship between factors is necessarily defined by mathematical functions.

SDM is a simulation model; therefore, the critical issue of the model is how accurately the interrelationships between factors are represented. In other words, factors like causal effect, feedback, and control source need to be identified and justified in the first place. In this respect, surveys of company personnel were conducted in the case study such that the factors and their weights were agreed upon.

The last indirect productivity measurement model, developed by Stewart [54], is a surrogate model based on utility theory and is used to measure productivity at plant levels. Similiar to the Delphi Technique, the Group Technique (NGT) was used in the surrogate model to rank the important measures of a plant performance and project their utility functions. The personnel involved in the NGT are responsible executives at various levels within the firm. Moreover, since there exists no empirical model for all plants, each plant has to determine the individualized important measures to formulate its overall performance. In the case study reported by Stewart, the following nine surrogate measures were used:

(1) Inventory turnover

(2) Percentage of direct labor covered by time standards

(3) Value added per direct labor hour

(4) Key machine efficiency

(5) Direct labor hour generation per direct labor hour employee

(6) Material identification and location accuracy

(7) Total operating quality cost per net sales dollar

(8) Internal schedule reliability

(9) Initial shipment service level.

After the surrogate measures were determined, utility curves were projected for these measures and further combined into a composite utility function which represents the productivity of the plant. To obtain such composite utility function, Stewart used the Keeney's[1] multiplicative multi-attribute utility model.

$$KU_t x + 1 = (Kk_1\ U_1\ x_1 + 1)(Kk_2\ U_2\ x_2 + 1)\ \ldots\ (Kk_9\ U_9\ x_9 + 1)$$

where, K is the scaling constant

k_i is the coefficient of surrogate measure i, i=1,...,9, with utility function $U_i(x_i)$ to be assigned

$U_t x$ is the composite utility measure of total productivity.

3-3. Additional Notes.

In addition to models, such as those in Sections 3-1 and 3-2, which measure the productivity of an entire plant or firm, much literature deals with the productivity of functional areas in a firm. Examples of these functional areas are quality control, data processing, warehousing, etc. The measures used in those functional areas are characterized as function-oriented productivities [4, 9, 44]. The average throughput time of warehouse operations is an example of a function-oriented productivity measure.

Aside from the models and concepts stated previously, a successful program of productivity measurement requires sound management. Carr [5] stated that a firm should gradually develop the system of productivity measurement by its scope and functions, and a formal productivity

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[1] Keeney, R. L., Raiffa, H., "Decisions with Multiple Objectives: Preferences and Value Trade-Offs", John Wiley and Sons, New York, 1976.

information system will provide management with one more useful tool in long-range planning. Carr listed three phases of a productivity program: (1) company and plant level comparisons to industry averages, (2) productivity measurement by functional grouping, and (3) identification of causal factors. Along with these three phases, he suggested that the firm start from labor productivity, develop its own price deflators to improve accuracy of measurement, and use value-added to represent its production output.

In regards to productivity management, Ksamsnak [33] presented his firm's experience in adding the productivity measurement to an existing management information system. Suggesting that the data for productivity measurement be obtained from the accounting system and that the implementation of a productivity program should be on a gradual basis, he concluded that, with some modifications of the existing system, the firm could report the trend of productivity gain or loss relative to the goals set for any time period.

IV. PRODUCTIVITY INFORMATION FOR MANUFACTURING

While the models and concepts presented in Chapter III are applicable to manufacturing systems in general, there are some additional considerations, regarded as important by this study, in providing productivity information for manufacturing.

4-1. Need of Productivity Information for Operating Management.

According to organizational theories, a firm basically consists of three levels of management: top, middle, and operating management. These management levels assume different responsibilities on the performance of the firm. In terms of their functions, top management determines the objectives of the firm, middle management acquires and controls the necessary resources to implement these objectives, while operating management is concerned with the definite and specific activities necessary to achieve these objectives [27]. In other words, through the structural organization, the overall goal of the firm is interpreted and broken down into sub-goals with which responsbilities are assigned and executions are made.

As one looks into the managerial hierachy, productivity information represents different meanings at different levels. For instance, productivity should relate to the ability of making profit if it can be useful for top management; however, it should refer to the ability of adding product value if middle and operating management are concerned. To meet these different functional needs, it is desirable to provide stratified, yet related, productivity measures for the various levels of management.

4-2. Responsibility Identification.

In addition to measuring productivities at the operating management level, the responsibility for productivity performance should also be assigned. One reason that PM has not been widely implemented is because productivity information has not been assigned to the specific responsibility centers. For example, when productivity is measured only at the firm level, the responsibility for such productivity performance may be assigned to the top executives. However, the top executives have no means to associate the firm's productivity with the detailed organizational units whose performances also contribute to the overall firm's performance.

In determining productivity performances for each responsibility center within a firm, it is necessary to look into the specific factors affecting the performance of the particular center (or work unit). Ideally, a work unit is only responsible for, and thus should be evaluated by, the factors which are under the control of the work unit. However, to include only the factors within the control of the work unit may be contradictory to the definition of total productivity. In order to resolve such a dilemma, some productivity measures which differ from the classical total and partial productivity measures may be necessary.

4-3. Integration of PM into Formal Information System.

Productivity-related information can only aid the management decision-making process when it is integrated into a formal, and regular, management reporting system. Such requirements become essential particularly for the operating management. One important benefit that an integrated productivity information system can provide is a fast delivery of productivity information to management. When manufacturing technologies advance and data collection becomes automatic, productivity information can be provided that is useful even for short-term production planning and control.

4-4. A Hypothetical Manufacturing Plant.

Sections 4-1, 4-2, and 4-3 have presented some arguments which also outline the attempt of this study to contruct a PM model for a manufacturing plant. It becomes necessary at this point to depict a manufacturing system to reinforce these arguments and pave a road for the subsequent chapters.

Conceptually, a manufacturing plant can be described in terms of its organizational structure and production characteristics. Traditionally, an organizational structure is used to designate the "chain of command" and "grouping of people". Production characteristics are used to describe the process of how and where operations are performed on the products within the plant. However, the traditional organizational structure needs to be modified to accommodate the concepts of PM, that is, the structure of the organization should include the input factors of machine, equipment, tool, energy, as well as people.

Figure 1 is an example of a modified organizational structure for a hypothetical manufacturing plant. Figure 1 was constructed by adding production resources into their corresponding organizational units, and is based upon the following three assumptions.

(1) An organizational unit must consist of either production resources or sub-organizational units. When an organizational unit consists of only production resources, it is termed a basic organizational unit.

(2) When a piece of equipment is jointly used by two or more organizational units, the equipment belongs to the higher level of organizational units. The difference between a machine and a piece of equipment is that a machine belongs to a basic organizational (work) unit whereas a piece of equipment is shared by multiple organizational units. Although an equipment item is a production resource, it does not belong to a basic organizational unit since the item of equipment is shared. Thus, a basic organizational unit does not have equipment and a non-basic organizational unit has a minimum of two organizational units, basic or non-basic.

(3) The production resources of an organizational unit may include human resources (labor), machines, equipment, tools, and energy. Overhead is not a production resource, but is a shared cost which comes from the "higher" organizational unit(s).

In the aspect of production characteristics, a job shop production is assumed in the hypothesized plant. Moreover, the following five assumptions are made.

(1) Product structure provides the link between operations and organizational units (or work units). Operations provide

functional information on time, machines, equipment, tools, and human resources.

(2) A parent item in the product structure may have multiple operations with a child item, but an operation can take place only in a single work unit.

(3) A work unit can produce standard and non-standard outputs. A standard output has a documented product structure and has a predetermined incoming product(s) (or material(s)) to the work unit; otherwise, it is a non-standard output.

(4) No alternate routing is permitted in the operational sequence for any product.

(5) Each job input to a work unit can be completed in a single shift. Thus, the productivity measurement system developed utilizes a one-shift reporting period.

It is believed that PM in the flow shop and mixed shop can be conducted in the same manner as that of the job shop. There exists no significant differences in PM for the three types of production shops since PM is only concerned with the inputs and outputs from a work unit.

Figure 2 shows the inputs, outputs, and production resources which are considered in this research. There are of course other factors involved in the production process, such as supervision, quality of working environment, etc. However, these are difficult to quantity and measure. Joined together, Figures 1 and 2 constitute the framework of the next chapter which presents the productivity models for the hypothesized manufacturing plant.

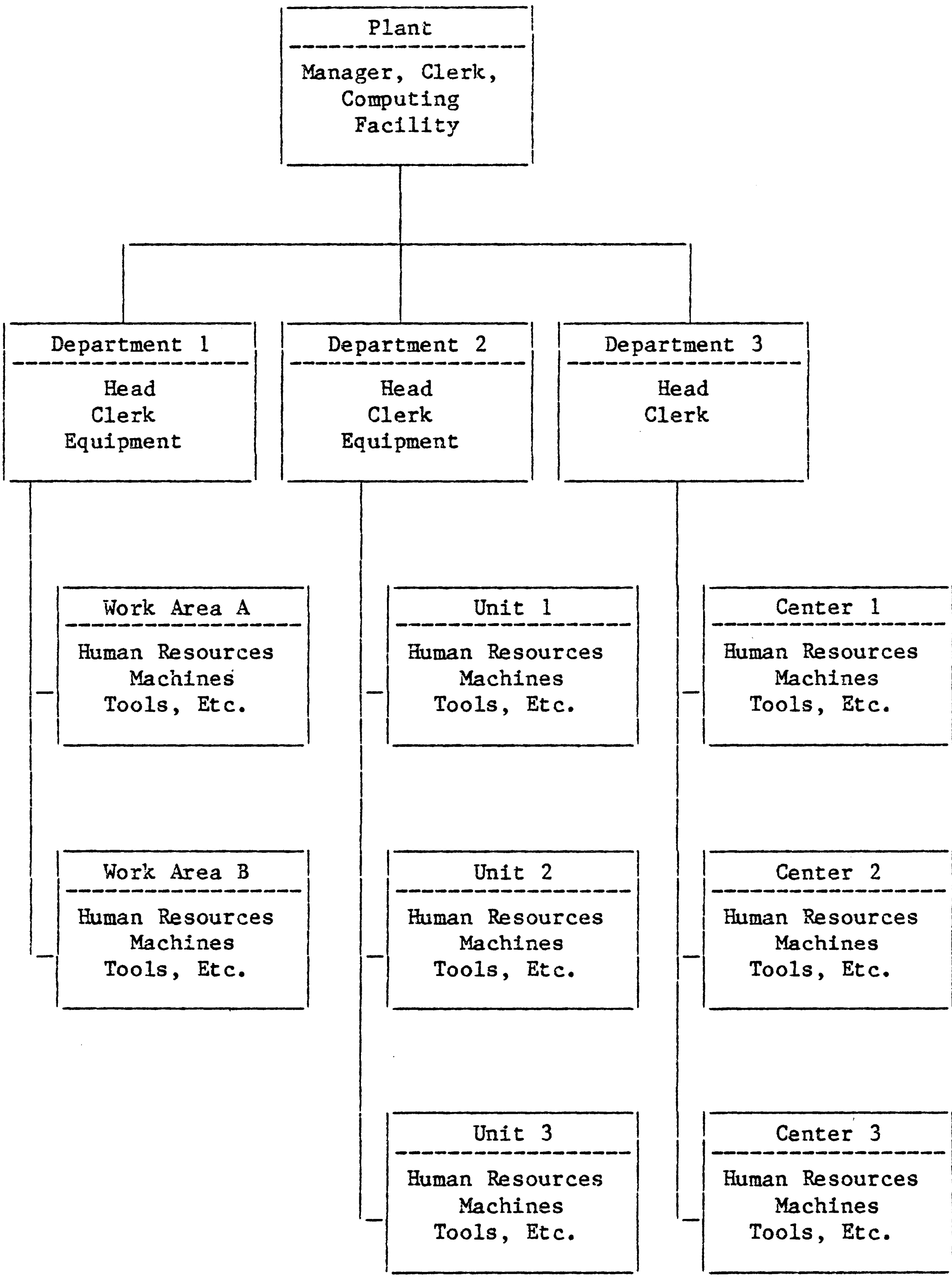


Figure 1. Example of Organizational Structure for a Manufacturing Plant

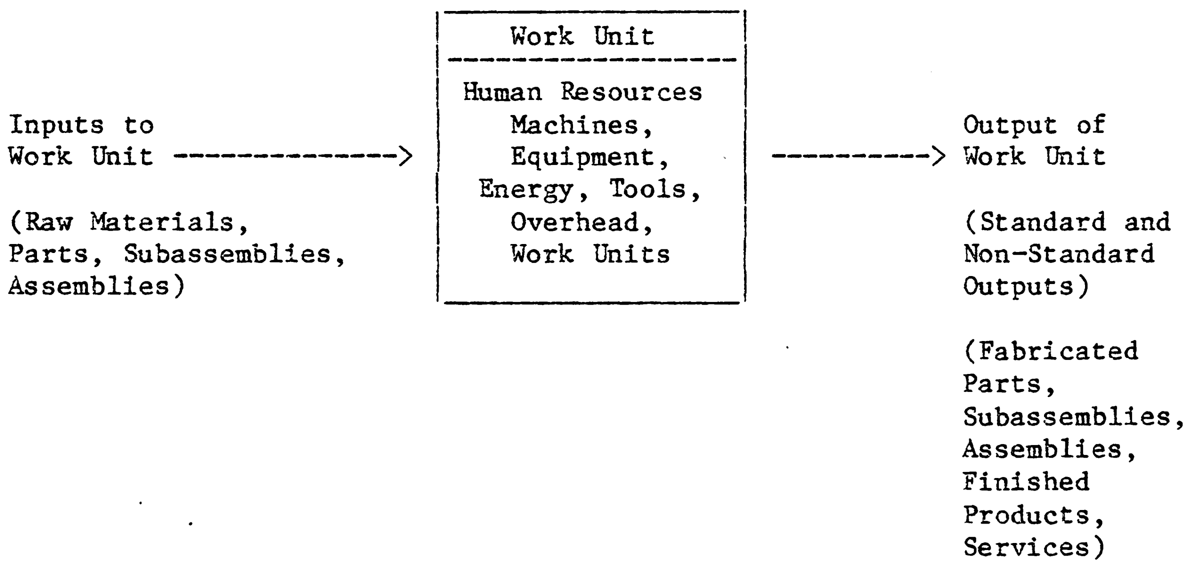


Figure 2. Inputs and Output of a Work Unit

V. MATHEMATICAL MODELS

The mathematical model developed in this study is based on the operational data of production resources according to an organizational grouping. There are two productivity measures in the model: time productivity and value productivity. Output of the time productivity is measured as production time and input is measured either as production time or as production cost. If input is the production time, the time productivity is the capacity utiilization. For the value productivity, output and input are both measured as production costs. A linear weighting is used to aggregate the productivity indexes. The organization structure in Figure 1 is used for the model demonstration.

5-1. Time Productivity.

Depending upon the data sources, time productivity can be computed in two ways. Data from work unit treat the work unit as a homogeneous operating unit and do not discriminate the differences of performance between the production resources within the same work unit. Data from production resources monitor the actual operations of individual inputs. The former is an aggregate form of the latter.

5-1-1. Work Unit As the Data Source.

In Figure 1, Area A is a basic work unit since only production resources are component elements. The total output, in time units, for Area A can be determined as follows:

$$TT_A = \left(\sum_{j \varepsilon J_A} Q_j \cdot T_j \right) + TN_A$$

Let J_A = the set of standard products produced by Area A

Q_j = the quantity of product j

T_j = the standard time of producing product j

TN_A = the time that Area A spends on non-standard products K_A,

where $TN_A = \sum_{k \varepsilon K_A} T_k$, and

T_k = the time spent on the non-standard product k.

Let ID_A be the idle time of Area A during the eight hour reporting.

The time productivity of Area A is then:

$$TPT_A = \frac{\sum_{j \varepsilon J_A} Q_j \cdot T_j + \sum_{k \varepsilon K_A} T_k}{8 - ID_A} \times 100\% \text{ , and} \qquad (5\text{-}1)$$

the capacity utilization of Area A is:

$$CU_A = \frac{\sum_{j \varepsilon J_A} Q_j \cdot T_j + TN_A}{8} \times 100\% \qquad (5\text{-}2)$$

Furthermore, since Area A and Area B are the component work units of Department 1 which itself has a department head, equipment, and a clerk as production resources, the time productivity and capacity utilization Department 1 are as follows:

$$TPT_1 = \frac{TPT_A \cdot OPC_A + TPT_B \cdot OPC_B}{OPC_A + OPC_B + OPCS_1} = \frac{TPT_A \cdot OPC_A + TPT_B \cdot OPC_B}{OPC_1} \qquad (5\text{-}3)$$

$$CU_1 = \frac{CU_A \cdot OPC_A + CU_B \cdot OPC_B}{OPC_A + OPC_B + OPCS_1} = \frac{CU_A \cdot OPC_A + CU_B \cdot OPC_B}{OPC_1}, \qquad (5\text{-}4)$$

Where

TPT_B is the time productivity of Area B,

CU_B is the capacity utilization of Area B,

$OPC_{A(B)}$ is the operating cost of Area A(B) and is the sum of costs of labor, machine, energy, tools, and overhead in Area A(B), and

$OPCS_1$ is the operating cost of Department 1 itself only, and is the sum of salary of the department head, wage of the clerk, costs of equipment, energy, tools, and overhead.

The variable OPC_A, consists of the following component costs:

LB_A is the total labor cost (of Area A)

MC_A is the total machine cost

EQ_A is the total equipment cost

ENG_A is the total energy cost

TL_A is the total tool cost

OH_A is the total overhead.

To differentiate the costs for the aggregation of work unit and the costs which are under the direct control of the individual work unit, an additional letter S is attached to the above variables. Consider, for example, Department 1, LBS_1 is the labor cost of Department 1 itself, and is the sum of the salaries of the department head and clerk. Likewise, MCS_1, EQS_1, $ENGS_1$, TLS_1, and OHS_1 can be defined in the same manner. Since machines are included only in the basic work units and no equipment can be included in the basic units, both EQS_A amd MCS_A are zero.

For each category, the sum of costs for component work units and the work unit itself is the total cost of that category for the whole work unit. Thus the sum of labor costs of Area A, B, and Department 1 itself is the total labor cost of Department 1. That is,

$$LB_1 = LBS_1 + LB_A + LB_B \tag{5-5}$$

By the same token,

$$MC_1 = MC_A + MC_B \tag{5-6}$$

$$EQ_1 = EQS_1 \tag{5-7}$$

$$ENG_1 = ENGS_1 + ENG_A + ENG_B \tag{5-8}$$

$$TL_1 = TLS_1 + TL_A + TL_B \tag{5-9}$$

$$OH_1 = OHS_1 + OH_A + OH_B \tag{5-10}$$

Since

$$OPC_A = LB_A + MC_A + ENG_A + TL_A + OH_A \tag{5-11}$$

$$OPC_B = LB_B + MC_B + ENG_B + TL_B + OH_B \tag{5-12}$$

$$OPCS_1 = LBS_1 + EQS_1 + ENGS_1 + TLS_1 + OHS_1 \tag{5-13}$$

$$OPC_1 = LB_1 + MC_1 + EQ_1 + ENG_1 + TL_1 + OH_1, \tag{5-14}$$

then

$$OPC_1 = OPCS_1 + OPC_A + OPC_B. \tag{5-15}$$

Equations (5-3) and (5-4) are in simplified form, based on the assumption that Department 1 does not have tangible products of its own. Operating costs are used as weighting factors for the time values in Equations (5-3) and (5-4). From Area A and B to Department 1 there is only one level of organizational structure. The time productivity of other higher organizational levels can be computed in a similar fashion.

5-1-2. Production Resource as the Data Source.

The Time productivity measurement for production resources is their time utilization. For example, a machine running 7 hours of an 8-hour shift results in a time utilization of 87.5%. Thus, the time utilization of a machine (UTY_M) in Area A is calculated as follows:

$$UTY_M = \frac{\sum_{j \varepsilon J_A} Q_j \cdot M_j + \sum_{k \varepsilon K_A} M_k}{8} \times 100\% \ , \qquad (5\text{-}16)$$

where M_j is the standard machine time of producing standard product j,

M_k is the machine time spent on non-standard product k.

The difference between T_j, T_k used in Equations (5-2) and M_j, M_k used in (3-1) is that T_j, T_k are the time for the whole work unit, whereas M_j, M_k are the pure machine times. Another alternative to obtain the time utilization is to monitor the idle time. That is,

$$UTY_M = \frac{8 - ID_M}{8} \times 100\% \ , \qquad (5\text{-}17)$$

where ID_M is the total machine idle time in an 8-hour shift.

Time utilization is applicable to labor, machines, and equipment. Suppose that the time utilizations for these three production resources obtained, then the total time productivity of Area A is calculated as follows:

$$TPT_A = \frac{\sum_A (UTY_L \cdot PAY_L) + \sum_A (UTY_M \cdot MAC_M)}{\sum_A (PAY_L + MAC_M) + ENG_A + TL_A + OH_A}$$

$$= \frac{\sum_A (UTY_L \cdot PAY_L) + \sum_A (UTY_M \cdot MAC_M)}{OPC_A} \quad (5\text{-}18)$$

and the capacity utilization of Area A is:

$$CU_A = \frac{\sum_A (UTY_L \cdot PAY_L) + \sum_A (UTY_M \cdot MAC_M)}{\sum_A (PAY_L + MAC_M)} \quad (5\text{-}19)$$

where UTY_L is the utilization of labor,

PAY_L is the labor cost,

MAC_M is the machine cost,

$\sum_A$ is the summation taken for Area A.

Further, PAY_L is the cost of individual labor, and LB_A is the total labor cost of Area A, or

$$LB_A = \sum_A PAY_L \quad (5\text{-}20)$$

The symbol, MAC_M is the cost of individual machine, and MC_A is the total machine cost of Area A, or

$$MC_A = \sum_A MAC_M \quad (5\text{-}21)$$

In Equation (5-18), TPT_A, is a weighted time utilization of production resources. The aggregate man, machine, and equipment utilizations at different levels can be obtained in a similar manner. The Aggregate machine utilization of Area A is shown below:

$$MU_A = \frac{\sum_A (UTY_M \cdot MAC_M)}{\sum_A MAC_M} \tag{5-22}$$

The aggregate machine utilization of the plant is conventionally named as the plant capacity utilization. Another form of aggregate machine utilization is derived from the partial productivity definition and is shown below:

$$UM_A = \frac{\sum_A (UTY_M \cdot MAC_M)}{OPC_A} \tag{5-23}$$

Rather than measuring the machine utilization, (MU), the UM shows the contribution from the machine utilization. The time productivity and capacity utilization for the higher production levels can be measured by using Equations (5-3) and (5-4).

5-2. Value Productivity.

The basic work units are the fundamental data source for value productivity measurement. The data from the production resources is excluded because the output of a machine depends on the combined contributions of machine, labor, and other production resources. Output used in the value productivity is added value, which is the value difference between the outgoing and incoming products to the work unit. In this study, value is represented by production cost, and the added value is sum of two costs: cost difference of standard products, and the cost of production resources used to produce non-standard products. The total factor productivity of Area A (TPV_A), is calculated as follows:

$$TFV_A = \frac{VAD_A}{OPC_A} \times 100\% = \frac{[\sum_{j\varepsilon J_A}(STO_j - STI_j) \cdot Q_j] + (OPC_A \cdot \sum_{k\varepsilon K_A} T_k)}{OPC_A} \times 100\%, \quad (5\text{-}24)$$

where VAD_A is the added value of Area A,

STO_j is the standard cost of product j, and

STI_j is the standard cost of input product with respect to the output product j and Area A.

For Department 1, the total factor productivity is:

$$TFV_1 = \frac{VAD_A + VAD_B}{OPC_A + OPC_B + OPCS_1} \times 100\% = \frac{VAD_1}{OPC_1} \times 100\%, \quad (5\text{-}25)$$

where VAD_B is the added value of Area B, and

VAD_1 is the added value of Department 1.

Using added value as the output allows addition of the added value of component work units. The total productvity (TPV) can be obtained by adding the costs of incoming products to both the numerator and denomenator of the total factor productivity, or

$$TPV_A = \frac{VO_A}{VI_A} \times 100\% = \frac{VAD_A + \sum_{j\varepsilon J_A} STI_j \cdot Q_j}{OPC_A + \sum_{j\varepsilon J_A} STI_j \cdot Q_j} \times 100\%$$

$$= \frac{\sum_{j\varepsilon J_A} STO_j \cdot Q_j + (OPC_A \cdot \sum_{k\varepsilon K_A} T_k)}{OPC_A + \sum_{j\varepsilon J_A} STI_j \cdot Q_j} \times 100\%, \quad (5\text{-}26)$$

and

$$TPV_1 = \frac{VO_1}{VI_1} \times 100\%, \qquad (5\text{-}27)$$

where VO_A is the output value of Area A.

VI_A is the input value of Area A.

It should be noted that, depending upon the product flow, Equation (5-28) may be differently expressed by the variables in Equation (5-26). Suppose Area A and Area B are two independent basic work units in Department 1, and the value of incoming products to Areas A, B are IP_A and IP_B, or

$$IP_A = \sum_{j \varepsilon J_A} STI_j \cdot Q_j \text{ , and}$$

$$IP_B = \sum_{j \varepsilon J_B} STI_j \cdot Q_j \text{ ,}$$

then the total productivity of Department 1 is given by:

$$TPV_1 = \frac{VO_A + VO_B}{IP_A + IP_B + OPC_A + OPC_B + OPCS_1}$$

$$= \frac{VO_A + VO_B}{IP_A + IP_B + OPC_1} \times 100\% \qquad (5\text{-}29)$$

Now suppose Area B depends upon Area A and receives the outputs of Area A as its inputs, the total productivity of Department 1 is therefore

$$TPV_1 = \frac{VO_B}{IP_A + OPC_A + OPC_B + OPCS_1} \times 100\%$$

$$= \frac{VO_B}{IP_A + OPC_1} \times 100\% \qquad (5\text{-}30)$$

Equation (5-29) and (5-30) are two different forms which provide different indexes for total productivity. In contrast, the total factor productivity, as the one in Equation (5-25), the measures for both cases (dependency and independency) are identical. For the independent case,

$$TFV_1 = \frac{VAD_1}{OPC_1} \times 100\% = \frac{VAD_A + VAD_B}{OPC_A + OPC_B + OPCS_1} \times 100\%$$

$$= \frac{(VO_A - VI_A) + (VO_B - VI_B)}{OPC_A + OPC_B + OPCS_1} \times 100\% \qquad (5\text{-}31)$$

For the dependent case,

$$TFV_1 = \frac{VAD_1}{OPC_1} \times 100\% = \frac{VO_B - VI_A}{OPC_A + OPC_B + OPCS_1} \times 100\% .$$

Since $VO_A = VI_B$, i.e., the output of Area A is the input of Area B, the above equation is equal to:

$$= \frac{(VO_B - VI_A) + (VO_A - VI_B)}{OPC_A + OPC_B + OPCS_1} \times 100\%$$

$$= \frac{(VO_A - VI_A) + (VO_B - VI_B)}{OPC_A + OPC_B + OPCS_1} \times 100\% , \qquad (5\text{-}32)$$

which is identical to Equation (5-31).

Partial productivities include labor, capital, and energy. Using the added value as the output, capital productivities (CPV) of Area A and Department 1 are shown below:

$$CPV_A = \frac{VAD_A}{MC_A + EQ_A + TL_A} \times 100\% = \frac{VAD_A}{MC_A + TL_A} \times 100\% \qquad (5\text{-}33)$$

$$CPV_1 = \frac{VAD_1}{MC_1 + EQ_1 + TL_1} \times 100\%$$

$$= \frac{VAD_A + VAD_B}{(MC_A + MC_B) + EQS_1 + (TL_A + TL_B + TLS_1)} \times 100\% \qquad (5\text{-}34)$$

The CPV measures how much of added value is contributed by one unit of capital investment. Partial productivities, using total value as the output can be obtained by adding the value of input products to the numerators of Equations (5-33) and (5-34). Again, the product flow needs to be taken into account to compile such partial productivities.

It deserves special attention that the operating costs and standard costs used in the mathematical models in this chapter include overhead costs which are generally regarded as non-controllable costs. An alternative approach is to discount the overhead costs from these costs such that a work unit is only measured by those controllable costs.

VI. COMPARISONS OF PM MODELS

6-1. Criteria of Comparison.

Even though the PM models are constructed for the same economic level - company or plant level, it is difficult to compare them since each model views the production system from a different angle. In essence, a PM model is more like a set of concepts and procedures than a set of mathematical formulas. In this sense, the criteria used in this chapter to compare PM models which include those in the literature survey (Chapter III) and the PMS, can not be exhaustive and free from subjectivity. Therefore, while judging the differences between the PM models, one should be aware that concepts and procedures of PM models deserve equal attention.

In spite of the above stated limitations, Table A is charted for the comparisons of ten PM models. Ten criteria of comparison in Table A are listed as follows.

(1) Approach of Measurement.

This refers to if the model uses direct or indirect measurement.

(2) Economic Level(s) of Measurement.

This refers to the economic level(s) that the model is constructed for. Since some models of company productivity are also applicable to the plant level, determinations of levels of measurement are based on either the nature or the case study of the model.

(3) Data Source of Output.

This refers to the data for the production output or the data for the overall performance of production system.

(4) Data Source of Input.

For direct measurement models, this refers to the data for production input. For indirect measurement models, this refers to the data for input factors affecting production output or performance.

(5) Measures.

This refers to measures used by the model to represent productivity of production system.

(6) Structure of Measurement.

This refers to how the productivity measures are constructed. The model is called aggregate when its data sources come from only "the" economic level under measurement. Otherwise, the model is called distributed.

(7) Flexibility of Measurement.

This refers to if the measurement can be made from different economic level(s). An aggregate model is inflexible since it is constructed for single economic level. A distributed model is flexible only if measurement can be made from alternative data sources or approaches.

(8) Reporting Period.

This refers to the shortest reporting time that the model aims to provide. Reporting period depends largely upon availability of production data and user's requirements upon productivity information.

(9) Forward-Looking.

All PM models have backward-looking ability; which means measurement is made after production is completed. Some PM models have forward-looking features because of their planning capability.

(10) Difficulty of Implementation.

This refers to the degree of difficulty in obtaining data and constructing measurement system. Rather than an empirical assessment, determination of such difficulty is based on a general production system.

Table A. Comparisons of Ten PM Models

Criteria / Models	Approach of Measurement	Economic Level(s) of Measurement	Data Source of Output
Kendrick & Creamer's Model	Direct	Firm	Aggregate Net Sales
SFM	Direct	Firm	Aggregate Net Production
OFM	Direct	Firm	Individual Products (Weighted by Average Marginal Cost)
EGS	Direct	Firm	Weighted Sum (by Price) of Outputs
APC	Direct	Firm	Aggregate Net Production
POM	Direct	Firm	Individual Net Sales (by Products)
Ernst's Model	Indirect	Plant	Aggregate Production Output
SDM	Indirect	Worker	Various Indicators of Performance
Stewart's Model	Indirect	Plant	Utility Curve for Overall Performance of Production
PMS	Direct	From Production Resources to Plant	Value-Added by Production Resources or Work Units

Table A. Comparisons of Ten PM Models (Cont'd.)

Criteria / Models	Data Source of Input	Measures
Kendrick & Creamer's Model	Aggregate Labor, Materials, Services, and Capital	Total and Partial Productivities
SFM	Aggregate Labor, Capital, Raw Materials & Purchased Parts, Other Goods and Services	Total and Partial Productivities
OFM	Distributed Costs (by Products) of Raw Materials, Personnel, Capital, Indirect Production and Purchase for Production	Total Productivity
EGS	Aggregate Labor, Capital, Materials, and other tangible Inputs	Total and Partial Productivities, Capacity and Fixed Investment Utilization
APC	Aggregate Labor, Capital, Materials, Energy, and Other Inputs	Productivity, Pricing Recovery, Cost Effectiveness Indexes & Variances
POM	Distributed Costs (by Products) of Human, Capital, Materials, Energy, and other Expenses	Total Productivity
Ernst's Model	Input Factors Affecting Production Change	Total Productivity
SDM	Interrelationship between Individuals, Organizational, and External Factors	Worker Performance Indexes
Stewart's Model	Surrogate Measures of Performance and Corresponding Utility Curves	Total Productivity
PMS	Distributed Costs (by Work Units) of Labor, Machines, Tools, Equipment, Energy, and Overhead	Total and Partial Productivities, Capacity Utilizations

Table A. Comparisons of Ten PM Models (Cont'd.)

Criteria / Models	Structure of Measurement	Flexibility of Measurement	Reporting Period
Kendrick & Creamer's Model	Aggregate Measurement	No	Quarter
SFM	Aggregate Measurement	No	Year
OFM	Distributed Measurement; Product-Oriented	Yes (from Products)	Quarter
EGS	Aggregate Measurement	No	Quarter
APC	Aggregate Measurement	No	Quarter
POM	Distributed Measurement; Product-Oriented	Yes (from Products)	Quarter
Ernst's Model	Aggregate Measurement	No	Year
SDM	Dynamic and Descriptive Measurement	No	Dynamic
Stewart's Model	Aggregate Measurement	No	Quarter
PMS	Distributed Measurement; Responsibility-Oriented	Yes (from Work Units)	Day

Table A. Comparisons of Ten PM Models (Cont'd.)

Criteria / Models	Forward-Looking	Difficulty of Implementation
Kendrick & Creamer's Model	No	Low
SFM	No	Medium
OFM	Yes	Medium
EGS	No	Low
APC	No	Low
POM	Yes	Medium
Ernst's Model	Yes	Low
SDM	Yes	High
Stewart's Model	Yes	Medium
PMS	Yes	Medium

6-2. Comments on Comparison of PM Models.

In addition to the criteria listed in Table A, the following two general comments on PM models are made:

(1) Since each PM model views production system in a distinctive perspective, the conclusion that one model is superior to another is subjective; it is the distinctive perspective that determines what measures and how these measures should be constructed.

(2) A PM model is an input-output model which can largely be understood from the elements (or factors) used in the production inputs and outputs. Consequently, availability of data for production inputs and outputs determines if a PM model can be implemented.

VII. IN-PLANT PRODUCTIVITY MONITORING SYSTEM

One of the objectives of this study is to develop an in-plant productivity monitoring system, based on the mathematical model in Chapter V. There are two phases of the development: identification of functional requirements and system design. The functional requirements are the specifications of functions that the system receives and provides. The functional requirements are the equivalents of the users requirements which are not available in this study. It should be noted that the real-world case study in the next chapter is to demonstrate the developed system, and is not an existing plant for initiating the system development. The system design determines the data, records, files, data base, and develops the programs for the functional requirements. Also noted is that the system requirements which deal with the hardware of data processing is not a concern of this study. The in-plant productivity monitoring system is abbreviated as "PMS" hereafter.

7-1. Functional Requirements of PMS.

The functional requirements are divided into 3 categories: system outputs, intermediate information, and system inputs. The system outputs, in turn, include output information, output formats, and output devices. The output information of the PMS consists of total factor productivity, time utilizations, and partial productivities. The production resources are measured in terms of time utilizations, whereas the responsibility centers are evaluated by their productivity performance.

Except for the time utilizations which are measured in time only; the total factor and partial productivities are measured in both time and value. Although an output report is a point-estimate of productivity, the output formats are the detailed, field-by-field reports, the productivity trends and the productivity comparisons can be automatically collected once the "points" are measured. The output device used in this study include hard-copy and terminal displays.

The intermediate information refers to the outputs between the initial system inputs and final system outputs. The intermediate information is necessary for the flexibility and subsystem approach of PMS. It is technically feasible to measure productivity in a single program; however, any modifications to such a program will be extremely difficult. In addition, the intermediate information provides the internal information which may be useful for management as well as other manufacturing subsystems. In the PMS, the intermediate information includes the following ten items.

(1) output value of work unit,

(2) value added by work unit,

(3) input value of work unit,

(4) input value without incoming products of work unit,

(5) value of production resource,

(6) output time of work unit,

(7) time added by work unit,

(8) input time of work unit,

(9) input time without incoming products of work unit,

(10) time equivalents of production resources.

The productivity measures can be obtained by taking the ratios by pairs. For example, the ratio of (2) and (4) is the total factor productivity and the ratio of (1) and (3) is the total productivity. For a production system which does not have information on actual input, productivity may be substituted by the measures such as (2) or (7).

The system inputs deal with data source, input format, and input device. There are two data sources: data for constructing system and data for updating system. Basically, data for constructing the PMS include organization structure, product structure, operation sheet, and production resources. The data for updating the PMS include production input, production output, and revisions of the constructed system. The input format can be flexible in the data entry, but must conform to the format of file definition before file processing. The input device is a remote terminal which is also used to receive the system output.

7-2. System Design of PMS.

PMS is developed on the MARK IV File Management System of Informatics, Inc. The communication between the MARK IV and the remote terminal is established by submitting jobs from CMS (Conversational Monitoring System) to MVS (Monitoring Virtual System) and receiving output from the MVS to the CMS virtual reader. The MARK IV is handled by the host computer, IBM 370/158 in batch processing. The system design of the PMS is illustrated in two sections: Section 8-2-1 concerns the data, record, file, and data base; Section 8-2-2 shows an example of system flow chart for programming the PMS.

7-2-1. Data, Record, File, and Data Base of PMS.

The data field is the most basic element in an information system. A data field is specified by field type and field length. Two basic field types are number (numerical field) and character (alphabetical field). Additional specifications such as number of decimal points for a numerical field may be needed to complete the description of a data field. The data fields used in the PMS are only those related to the productivity measurement. Consider inventory record for example, the inventory number and description may be needed for the inventory listing or other control purposes. In the PMS, inventory description is excluded since the description and inventory number are in one-to-one correspondence. The inventory data needed for productivity measurement are inventory number, measuring unit, base cost, and current cost. For immediate retrieval and to avoid excessive data processing, certain data, such as production time, may be desirable in the inventory record even though such data can be obtained by processing other existing data fields.

After specifying the data fields, records can be constructed. A record is a string of related data fields, designed for the applicational requirements. The MARK IV uses record key to access records. The data fields of a record can be retrieved by their record key which itself can be a data field. The example of inventory record may use inventory number as the record key. A record can be specified by three characteristics: structure, type, and length. The record structure is the interrelationship between data fields. If no interrelationship exists between the data fields except their association with record key, the record is called "flat". Otherwise, the record is called "structured". There are two record types: variable record and fixed record. The record length for a variable record changes continously as needed, whereas the record length for a fixed record is a constant. The MARK IV requires variable record length for a structured record. For the PMS, the inventory record is a flat record, and the product structure is a structured record.

The data file is a collection of records of same format. A data file is called flat or structured when its records are flat or structured. In MARK IV, a file definition completely describes the data field, record, and data file. The definitions of files for the PMS are illustrated in Appendix B. Figures 3 and 4 illustrate definitions of unstructured and structured files. The details of these file definitions are listed next to the figures. It should be noted that a file definition in the MARK IV can be applicable to several data sets (or physical data) in the data base. In other words, a master file and a transaction file may use same file definition. Conceptually, file definitions and data sets can be viewed as two separate things. If the data fields and records of a data set match the formats of a file definition, the data set is definable by the file definition. Also noted is that a file definition must be specified when a data set is activated. The file terminologies used in the MARK IV include Master file, Transaction file, Coordinate file, and Subfile; these files are named according to their roles in a file processing.

The data file is also characterized by how the records are organized. The files in the PMS are sequential files (as opposed to random files) which sequentially organize the records according to the record key(s). To obtain a certain record from a sequential file, the search starts from the first record by comparing the record key; a mismatch of record key will terminate the search. A sequential file can be in increasing or decreasing order of record key(s). The files for the PMS are in increasing order.

The data base for the PMS is handled by the MARK IV file management system. A file directory automatically retrieves and stores the files specified by the job control cards. Since some files of the PMS have structured records, the data base is in a simple hierachical structure. The data fields at the lower levels and segments can only be retrieved by tracing down from the first level. Figure 5 shows the links between the master and transaction files for the PMS. The arrows on Figure 5 point to the record keys and show the directions of data retrieval.

7-2-2. Sample System Flow Chart.

Since the MARK IV is a file management system, its' programming differs from those programming languages such as FORTRAN or COBOL. The MARK IV program treats files as the basic entities. Within a MARK IV program, there may be a series of programming steps and each programming step can be a stand alone processing. Thus, a programming step of the MARK IV is equivalent to a program using the FORTRAN or COBOL language. The programming step is called "STEP" hereafter.

A STEP processes files based on the record key of a master file. If there are more than one master file in one STEP, the remaining files (other than the selected master file) are called coordinate files. Another input to a STEP is the transaction file which is used to update the master file. The output of a STEP may include updated master file, coordinate files, subfiles, and reports. The subfile is a temporary storage file needed for the applications in the subsequent STEP(s) or other job runs. The report is an information print-out. All files, except reports are retrieved and stored in the formats of their file definitions. Furthermore, all files except subfiles in a STEP must have the same record key of the master file.

A sample MARK IV program under the IBM 370/158 is included in the Appendix F. The program starts with the sign of P/* (remark) and ends with the sign of // which terminates the program run (or job run). It should be noted that the sign of P/* can be added anywhere in the program except the program body which begins and ends with RC (Run Control) cards. The program name consists of two parts - file name and file type, and is specified in the beginning documentation. The file type of program is always CNTL. The sample program is OTV CNTL (see Appendix F) which processes the overall total value of work units; the overall total value of a work unit was defined in Chapter VII. The system flow chart of the OTV CNTL has 9 STEPs (STEP 1 to STEP 9) and is shown in Figure 6. Other programs are structured in the same manner and are explained in Section 7-2-3.

7-2-3. PMS Programming.

The computer programs of PMS are alphabetically collected and explained below.

ITEMCALL CNTL: calculates direct costs of all inventory items which include raw materials, parts, assemblies, and finished products. The direct cost consists of the costs of materials, labor, machines, energy, and tools.

ITEMTALL CNTL: calculates operation time of all inventory items.

OPV CNTL : processes partial inputs of all work units. The partial inputs include labor, capital, and energy. In contrast to SPV CNTL, the partial input of OPV is the sum of partial input of work unit itself and the subordinate work units.

OTV CNTL : processes total input of all work units. The total input is the sum of partial inputs of OPV CNTL.

PPTYVALL CNTL: calculates partial productivities of all work units. The partial productivities include labor, capital, and energy productivities. The output used in the productivity ratio is measured in production cost.

PTYTALL CNTL : measures total productivity of all work units. Both input and output of productivity ratio are measured in time.

PTYTIO CNTL : measures total productivity of the work units which have non-standard inputs and outputs. Both input and output are measured in time.

PTYVALL CNTL : measures total factor productivity of all work units. Both input and output are measured in production costs.

PTYVIO CNTL : calculates value-added of work units which have non-standard inputs and outputs.

SPV CNTL : processes partial inputs of all work units. The partial inputs do not include inputs of subordinate work units.

STV CNTL : processes total input of all work units. The total input is the sum of partial inputs of SPV CNTL.

TADD CNTL : calculates time-added of all work units.

UTYALL CNTL : measures machine and manpower utilizations.

VADD3 CNTL : calculates value-added of all work units.

```
    00000000011111111112222222222333333333344444444445555
    12345678901234567890123456789012345678901234567890123
01P/* DEFINITION OF EMPLOYEE FILE
02EMP    RC
03EMP    FDEMP      BF  40
04EMP    L0EMP-NO         1  9C1
05EMP    L0LB-CD         10  4C
06EMP    L1LB-CD                            LABOR
07EMP    L2LB-CD                            CATEGORY
08EMP    L3LB-CD                            CODE
09EMP    L0PAY-BASE      14  7Z Y2
10EMP    L1PAY-BASE                         BASE YR
11EMP    L2PAY-BASE                         PAY RATE
12EMP    L0PAY-CURR      21  7Z Y2
13EMP    L1PAY-CURR                         CURRENT
14EMP    L2PAY-CURR                         PAY RATE
```

FIGURE 3. DEFINITION OF A FLAT FILE

The fourteen lines (01 - 14) in Figure 3 are sequentially explained as follows:

01 is the remark (with initials P/*) of this file definition.

02 specifies the name of this run as EMP by using Run Card (RC). The run name (EMP) is used throughout the run (from line 02 to line 14).

03 is the File Definition (FD) of file EMP.

BF 40 = B is to generate detailed output of definition run.
F means the EMP is a fixed-record file.
40 means the logical record length is 40 bytes.

04 specifies the field EMP-NO. For a data field, L0 is the specification line, whereas L1 to L9 are the remark lines.

1 9C1 = 1 means the field starts from the 1st byte.
9 means the field has 9 bytes.
C means the field is a character string.
1 means the field is the record key.

05 specifies the field LB-CD.

10 4C = 10 means the field starts from the 10th byte.
4 means the field has 4 bytes.
C means the field is a character string (and is not a record key).

06 is the first remark (L1) of LB-CD. The remark is LABOR.

07 is the second remark (L2) of LB-CD. The remark is CATEGORY.

08 is the third remark (L3) of LB-CD. The remark is CODE.

06,07,08 are the joint remarks of LB-CD as LABOR CATEGORY CODE.

09 specifies the field PAY-BASE.

14 7Z Y2 = 14 means the field starts from the 14th byte.
7 means the field has 7 bytes.
Z means the field is a numerical field.
Y2 means the field has 2 decimal points.

10,11 are the first and second remarks of PAY-BASE. The joint remark is BASE YR PAY RATE.

12 specifies the field PAY-CURR.

21 7Z Y2 = 21 means the field starts from the 21st byte.
7 means the field has 7 bytes.
Z means the field is numerical.
Y2 means the field has 2 decimal points.

13,14 are the first and second remarks of PAY-CURR. The joint remark is CURRENT PAY RATE.

It should be noted that each line is an image of a card. For the above 14 lines, the positions of codings are also restricted in the MARK IV. Both run name and field name can not exceed 8 characters each. Column 22 to 26 is for the starting byte of data field and is right-justified. Column 27 to 29 is for the length of data field and is also right-justified. The designations of field type, decimal point, and output formating are coded in the reserved columns. The remark of field must be in Column 44 to 51. There are more features available in the MATK IV but are not shown in this example.

```
  00000000011111111112222222222333333333344444444445555
  12345678901234567890123456789012345678901234567890123
01P/* DEFINITION OF PRODUCT STRUCTURE FILE
02PS      RC
03PS      FDPS       BV2000
04PS      L0ITEM-P    11    1 11C1
05PS      L1ITEM-P                           PARENT
06PS      L0ITEM-C    11  12  22    2
07PS      L0ITEM-S    22    1 11C1
08PS      L1ITEM-S                           CHILD
09PS      L0QTY       22  12  6Z  3
10PS      L1QTY                              QUANTITY
11PS      L0OP-NO     22  18  6Z        Z
12PS      L1OP-NO                            OP NO
13PS      L0WK-UT     22  24  9C
14PS      L1WK-UT                            WK UNIT
```

FIGURE 4. DEFINITION OF STRUCTURED FILE

01 is the remark of this file definition.

02 is the Run Card (RC) with the run name PS.

03 is the file definition of PS.

B = generates detailed output of this definition run.
V = the PS is a variable record file.
2000 = the maximum record length is 2000 bytes.

04 is the specification of field ITEM-P.

11 1 11C1 = the first 1 means first segment.
the second 1 means first level.
the third 1 means the field starts from the first byte.
the next 11 means the field has 11 bytes.
C means the field is a character string.
the last 1 means the field is the segment key.

05 is the remark of ITEM-P. The remark is PARENT.

06 is the specification of field ITEM-C.

11 12 2Z 2 = first segment, first level.
it starts from the 12th byte.
2 bytes long, and is a numerical field (Z).
the last 2 means the field is a count field for the second level. Count field is a link between two adjacent levels in a structured file.

07 is the specification of field ITEM-S which is in the 2nd segment of 2nd level. It starts from the first byte, has 11 bytes, is a character string (C), and is the segment key.

08 is the remark of ITEM-S. The remark is CHILD.

09 is the specification of field QTY which is in the second segment of second level. It starts from the 12th byte, has 6 bytes, and is a numerical field (Z). The 3 in the last means the field has 3 decimal points.

10 is the remark of QTY. The remark is QUANTITY.

11 is the specification of field OP-NO which is in the second segment of second level. It starts from 18th byte, has 6 bytes, and is a numerical field (Z). The Z in the last means the leading zeros of the field are not omittable.

12 is the remark of OP-NO. The remark is OP NO.

13 is the specification of field WK-UT which is in the second segment of second level. It starts from the 24th byte, has 9 bytes, and is a character string (C).

14 is the remark of WK-UT. The remark is WK UNIT.

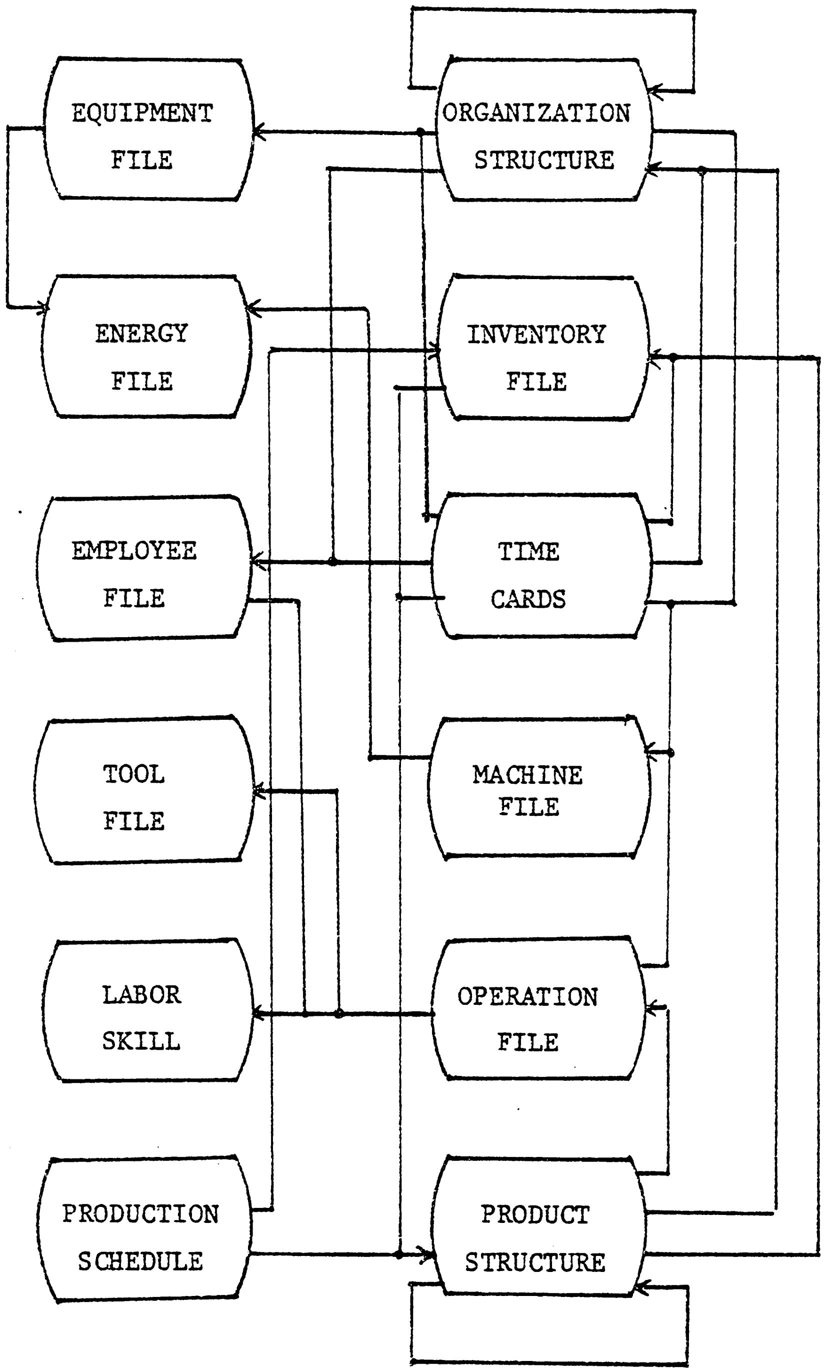


FIGURE 5. LINKS BETWEEN MASTER AND TRANSACTION FILES.
(the arrows point to the record keys)

FD = File Definition of the file on the left.

DS = Data Set of the file on the left. DS with A88888. is the permanent data set; DS with && is the temporary data set and will be erased after the job run.

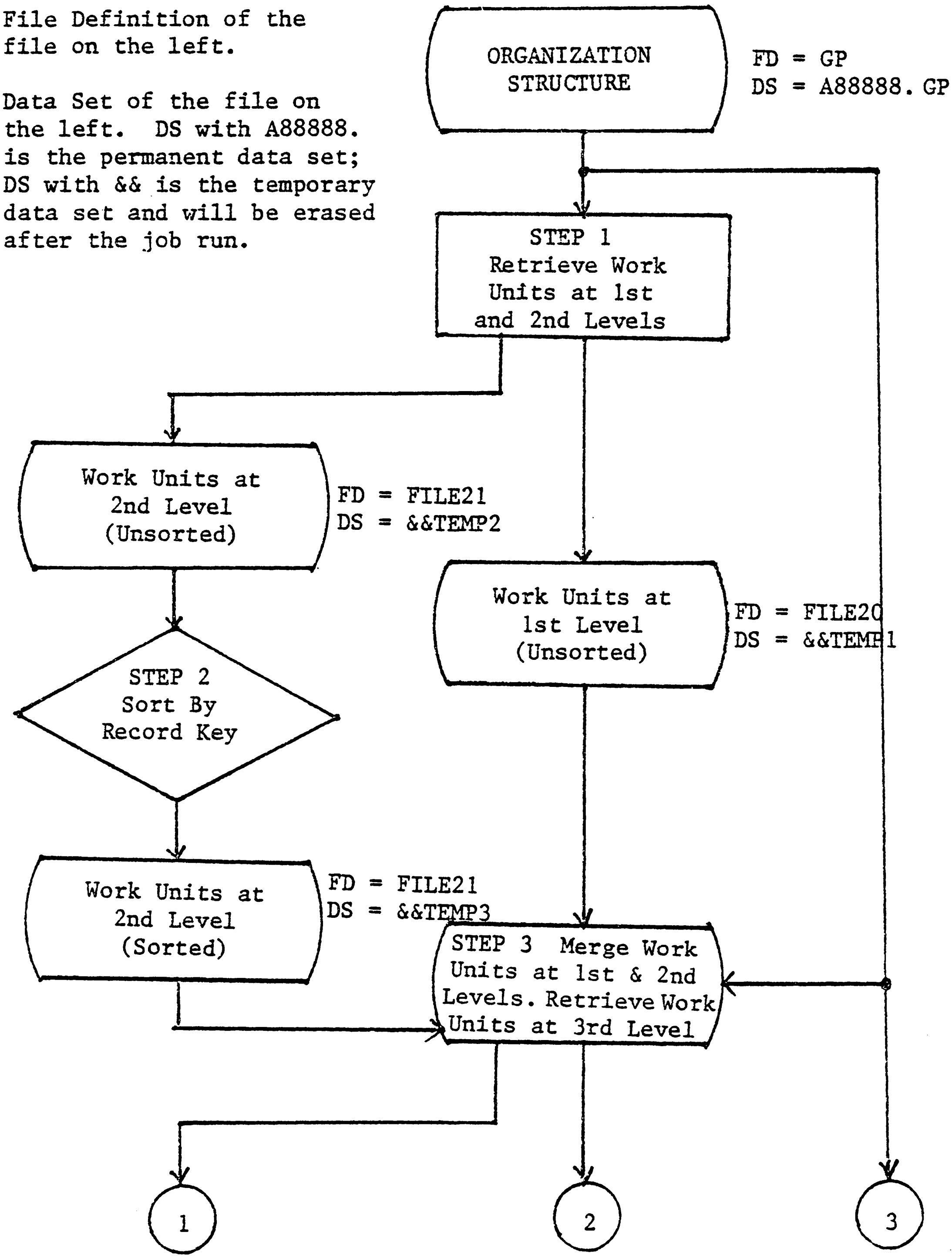


FIGURE 6. SYSTEM FLOW CHART OF OTV CNTL.

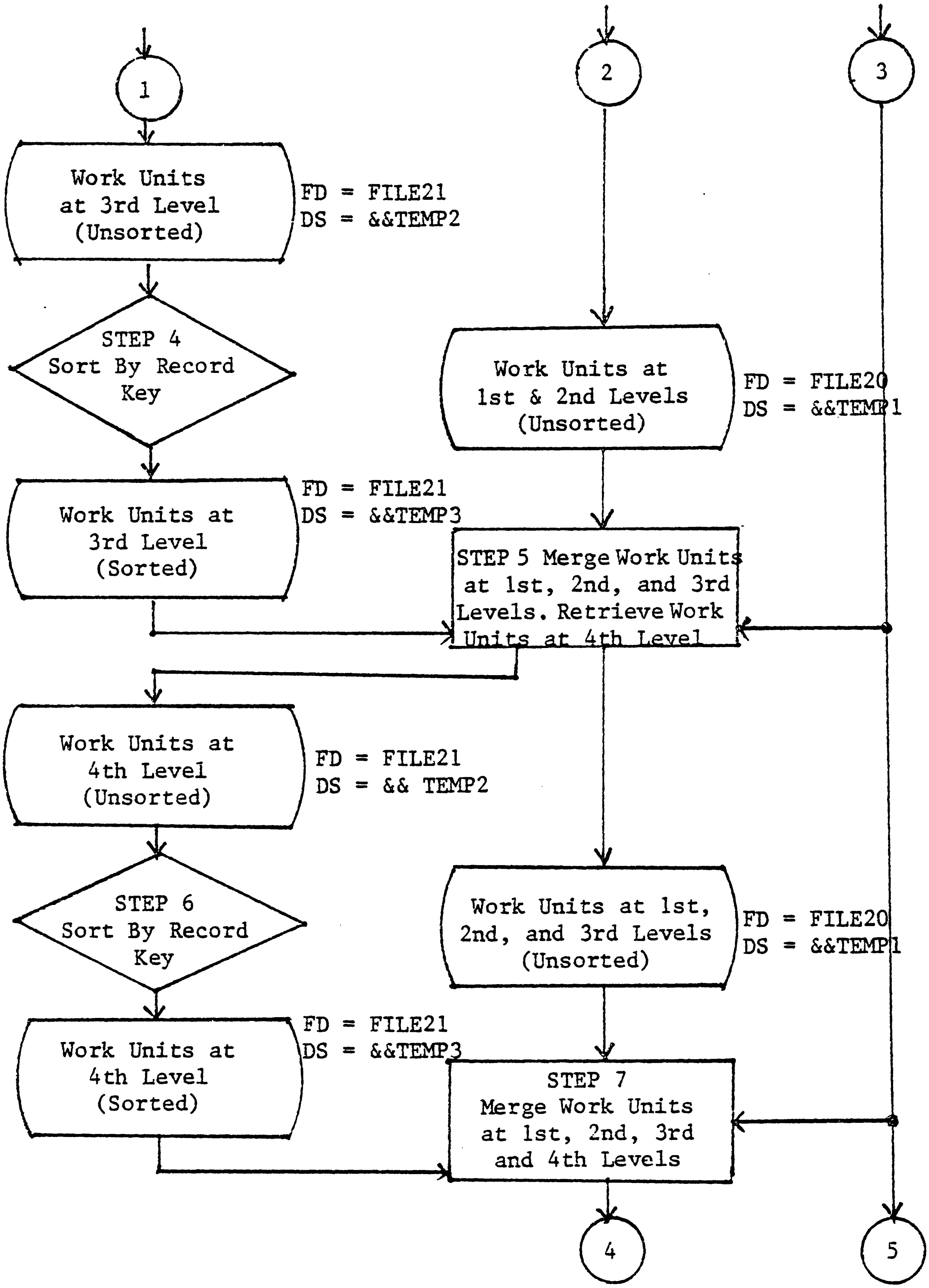
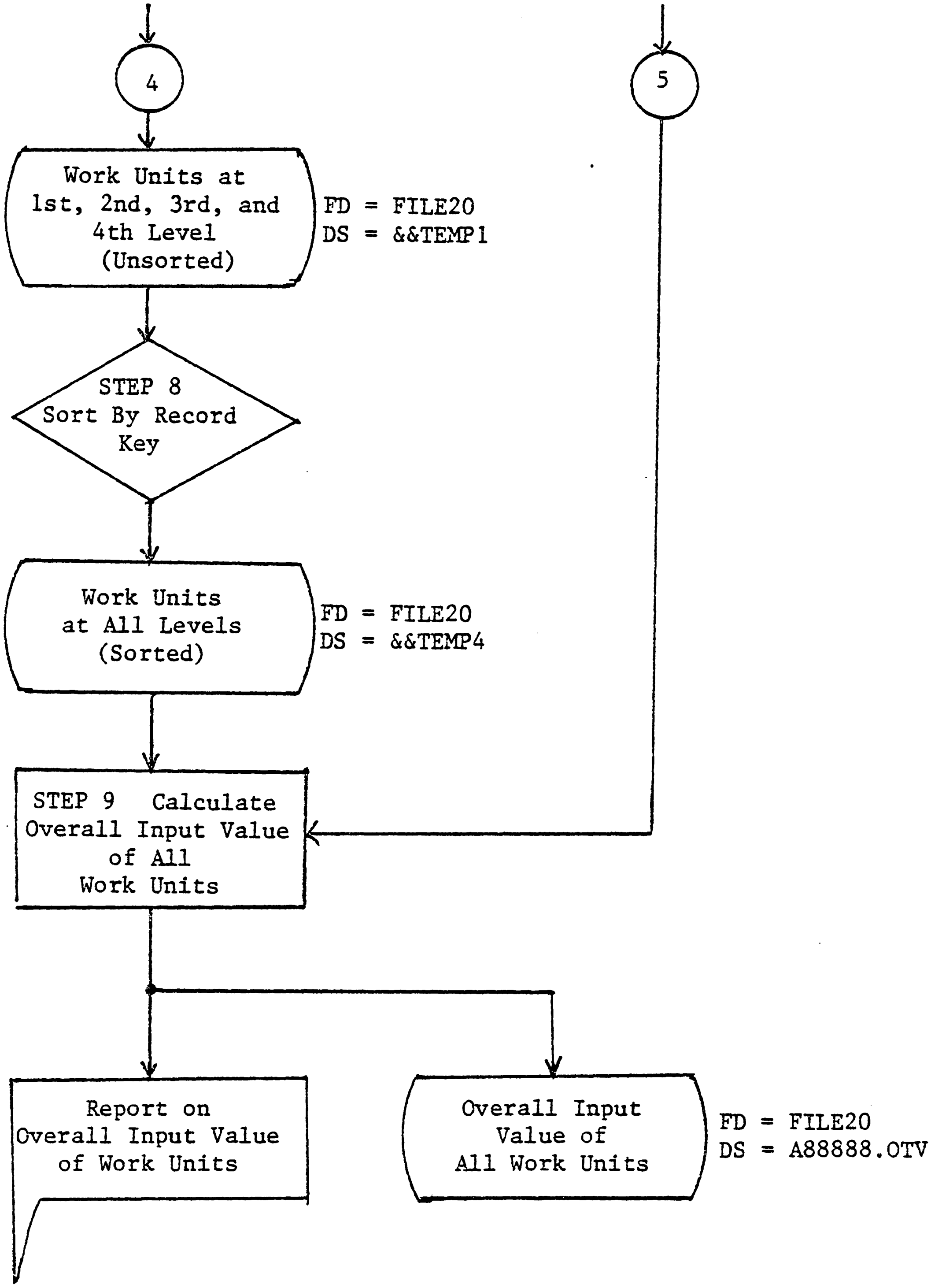


FIGURE 6. SYSTEM FLOW CHART OF OTV CNTL (Cont'd)



*Report(s) can be generated at each STEP for program debugging and other applications.

FIGURE 6. SYSTEM FLOW CHART OF OTV CNTL (Cont'd)

VIII. A CASE STUDY OF PMS

8-1. Data Source.

In order to demonstrate the PMS, Harvey Hubble Incorporated, Lighting Division in Christiansburg, Virginia was brought into this study. The Division is a medium-sized manufacturing facility, producing more than 1000 types of lighting fixtures. Among its 500 total employees, approximately one half is direct labor. The Division made operating data available in two ways. It permitted this investigator to observe the production operations. It also provided recorded data from its data files. Since PMS is developed for manufacturing, several supporting departments such as Engineering Design, Marketing in the Division are combined and treated as a single Service department.

Appendix C and D list the data for constructing the master and transaction files. These data are obtained from two sources: supplied by the Division and simulated by this study. Table B shows the data sources with respect to each data file. It should be noted that portions of data from the Division has been modified somewhat to protect confidentiality. From Table B, 62% of the required data, counted by the data elements, is supplied by the Division. For the remaining 38%, some simulated data will be replaced by the real data when the Material Requirements Planning is implemented by the Division. Finally, in order to obtain all the real data required by PMS, the Division also needs to adjust the historical costs of inputs and outputs into their counterparts at the base period.

Table B. Data Sources of PMS Case Study

File Name	Data Supplied by the Division	Simulated Data
EMPLOYEE	Employee No., Labor Category Code, Current Pay Rate	Base Pay Rate
ENERGY	Energy Code, Unit of Measure, Current Price	Base Price
EQUIPMENT	Equipment No., Energy Code	Lease Value, Consumption Rate, Impact Weight Index
ORGANIZATION STRUCTURE	Group No. (Work Unit), Group Level, Machine No., Employee No., Equipment No., Subordinate Group No., Overhead (partial)	Overhead (partial)
INVENTORY	Inventory No., Unit of Measure, Current Cost, Operation Time, Base Cost	
TIME CARD OF NON-STANDARD PRODUCTS	Work Unit, Output Item, Quantity Completed, Date	Job No., Input Item
TIME CARD OF STANDARD PRODUCTS	Work Unit, Job No., Output Item, Quantity Completed, Date	Completion Time in Hour, Minute and Second
MACHINE	Machine No., Energy Code	Lease Value, Energy Consumption, Impact Index

Table B. Data Sources of PMS Case Study (Cont'd.)

File Name	Data Supplied by the Division	Simulated Data
OPERATION SHEET	Operation No., Standard Time, Machine No. (partial)	Tool Code, Minimum Operation Time, Labor Time, Labor Skill Code, Machine Time, Machine No. (partial)
OPERATION STRUCTURE	Operation No.	
PRODUCT STRUCTURE	Parent Item, Child Item, Quantity Used	Operation No., Work Unit
PRODUCTION SCHEDULE	Item No., Weekly Demand, Quantity Backlog	
LABOR SKILL		Skill Code, Base Pay Rate, Current Pay Rate
TOOL	Tool Code (partial)	Lease Value, Impact Index

Total no. of files:	14
Elements of supplied data:	41
Elements of simulated data:	25
Percentage data, actual:	62%
Percentage data, simulated:	38%

8-2. Output Reports

The output listings of PMS with the input data of Section 8-1 are shown in Appendix E. These output listings have same file names as of their corresponding programs in Section 7-2-3 and have OUT as their file type. The output listings are alphabetically sorted by the file names which, along with remark (P/*), file type, and output documentation, are at the top of output listings. For illustration purposes, three outputs - PPTYVALL, PTYVALL, TADD are presented next.

PPTYVALL OUT (its program is PPTYVALL CNTL) is the output of partial productivities and has reporting fields of WORK UNIT, TOTAL VALUE ADDED ($), LABOR INPUT ($), LABOR PRODUCTIVITY, CAPITAL INPUT ($), CAPITAL PRODUCTIVITY, ENERGY INPUT ($), ENERGY PRODUCTIVITY. The partial productivities are the simple ratios of the TOTAL VALUE ADDED and corresponding input factors; these ratios can be converted into indexes (%) by multiplying 100%. For example, the work unit ASSEMBLY1 uses $139.84, $103.20, and $45.56 of labor, capital, and energy to produce $2073.08 of added value to the incoming products. In terms of percentage of individual inputs to the total input, labor is 48%, capital is 36%, and energy is 16%. Also noted in the listing is that an asterick (*) is printed when the denominator is zero. Mathematically, this asterisk denotes infinity, but it only shows the lack of input factors for the productivity measurement.

In addition to the partial productivities, total factor productivity is shown in PTYVALL OUT. The reporting field - TOTAL FACTOR PRODUCTIVITY is the ratio of TOTAL VALUE ADDED and TOTAL VALUE INPUT which takes the sum of partial inputs of the the PPTYVALL OUT. For work unit ASSEMBLY1, the total input is $288.60 and total factor productivity is 7.18 which means that ASSEMBLY1 uses $1 of total input to generate $7.18 of total value added in this particular work shift. It should be noted that asterisk (*) does not appear in the total factor productivity since a work unit must have production resources.

The third example of reports is time productivity - TADD OUT in which work unit ASSEMBLY1 contributes 634.15 minutes of total time added and achieves 132.11% (634.15/480) of time productivity. In other words, the ASSEMBLY1 uses 1 minute of its operation time to add value equivalent to 1.32 minutes of standard time to the output products.

It is important to note that the output reports generate absolute productivities which are the foundations of productivity trends and input substitutions. Since productivity trends and input substitutions are comparisons of historical absolute productivities, it becomes necessary to transform the outputs of absolute productivity into indexes.

IX. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

9-1. Summary of PMS.

A disaggregated productivity measurement model for manufacturing plant has been developed in this study, namely, the productivity monitoring system (PMS). This system combines many features of PM models available in the literature and has the following specifications.

(1) PMS is based on using production efficiency to measure manufacturing productivity directly. It is dependent upon the structure to provide the productivity bottom-to-top operating management.

(2) PMS uses classic total and partial productivity measures for each of the responsibility centers and uses utilization factors for the production resources in manufacturing. The inputs are human resources, machines, materials, equipment, tools, energy, and overhead; the outputs include standard and non-standard products. Among the inputs, materials are external to the responsibility centers.

(3) The measuring units used in the PMS are time and value. Value added is used as the numerator of productivity ratios since materials are external to the responsibility centers. When time is the measuring unit, it needs to be value-weighted for the responsibility centers.

(4) PMS is flexible in the degree of aggregation; it is not essential to have data from the basic production resources or from the basic work units; the data could be in aggregate form.

(5) PMS can be implemented as an independent information system, but also can be a subsystem of the general information system for manufacturing.

(6) PMS extends productivity measurement, which is normally a post-production measurement, into productivity projection for pre-production planning. The comparisons used in PMS are the productivity trends over time and the productivity discrepancies between the pre-production estimates and post-production measurements.

For the demonstration of PMS, some real operating data, estimated to be approximately 60% of the required data, has been provided by Harvey Hubble Incorporated, Lighting Division, in Christiansburg, Virginia. The Lighting Division is considering the installation of full-scale PMS after completing the installation of a Material Requirements Planning (MRP) system. This study suggests that computerized shop floor control should be implemented after the MRP to ensure the success of PMS.

9-2. Conclusions of This Study.

This study leads to the following six conclusions for productivity and its measurement. Hopefully these conclusions will contribute to the understanding of the nature of productivity.

(1) Productivity is a measure of economic means. However, other measures such as profitability, effectiveness, efficiency are interwoven and in practice are often interchangeable with productivity. This study identifies the definition of productivity at the production level and concludes that

different degrees of the mix of profitability and efficiency. Within the same production system, productivity, profitability, and efficiency are all under the ultimate measure - effectiveness.

(2) The term "productivity" is relative and used for various purposes and applications. The meaning of productivity has never been agreed upon in the past and will not be agreed upon in the near future. The increasing concern for productivity is due to the fact that only the growth of productivity can ensure the advancement of living standards.

(3) If productivity is measured in its classic form, i.e., the ratio of total output and total input, productivity will lose much of its popularity because classic productivity largely embraces the meaning of physical productivity which brings less attention to management than the economic productivity measures. In practical terms, what productivity means to management is that it is the ability to compete in general and to be profitable in particular.

(4) Classical productivity measures are not able to answer all questions from management regarding the firm's productivity because these measurements are limited in providing information for productivity analysis; this is especially true for the operating management. The reason that classical productivities should be measured at the operating level is that they truely represent the operational performance of overall system and reflect the combinatorial contributions of system inputs.

(5) An ideal productivity measurement system should be consistent in providing relevant and accurate productivity information, flexible in the aggregation of system performances, able to capture the system behaviour, and at the same time be easy to integrate into the general information system.

(6) PMS is a systematic, bottom-to-top approach in measuring manufacturing productivity. PMS differs from the traditional PM models in its features of fast updating and reporting, operational basis, responsibility identification, and flexibility of implementation. From the operational control viewpoint, PMS can provide aggregate information on overall system performance which aids planning the requirements of production inputs.

9-3. Recommendations for Further Study.

From the decision-making viewpoint, productivity indexes have rather limited capability in the planning and decision-making process because causal effects are not shown in the measures. Thus, further study on PM should focus on what factors affect the productivity performance and how. Along this direction of study, network modeling, simulation, and econometrics can be of great use in the determination and justification of interrelationships between the system factors. In addition, the techniques of optimization will also be useful in obtaining the optimal system performance.

Further study is also needed for the service productivity. Because of many intangible factors involved in service productivity, the survey type of techniques, such as the Nominal Group Technique, may be needed. In the measurement of service productivity, consistency is more important than accuracy in the selection of criteria.

Further study should place more emphasis on economic productivity than on physical productivity, particularly when information is provided for the upper levels of management. Nonetheless, at the plant level and below, the approaches used in PMS remain appropriate. It is believed that as production technologies become more integrated and computer oriented, PMS will be automatically implemented. The weakness of PMS is its limited planning capability. To enhance accuracy of measurement and planning capability, it will be necessary to incorporate OR-based models, such as value decision model for production resources into PMS. Moreover, further study on the PMS can be directed on the modifications of costs used in the mathematical models. One example of these modifications is to discount the overhead costs from the standard costs of products and from the operating costs. The philosophy of monitoring the performance of a production system is to reflect the system performance based on the factors that the system is responsible for.

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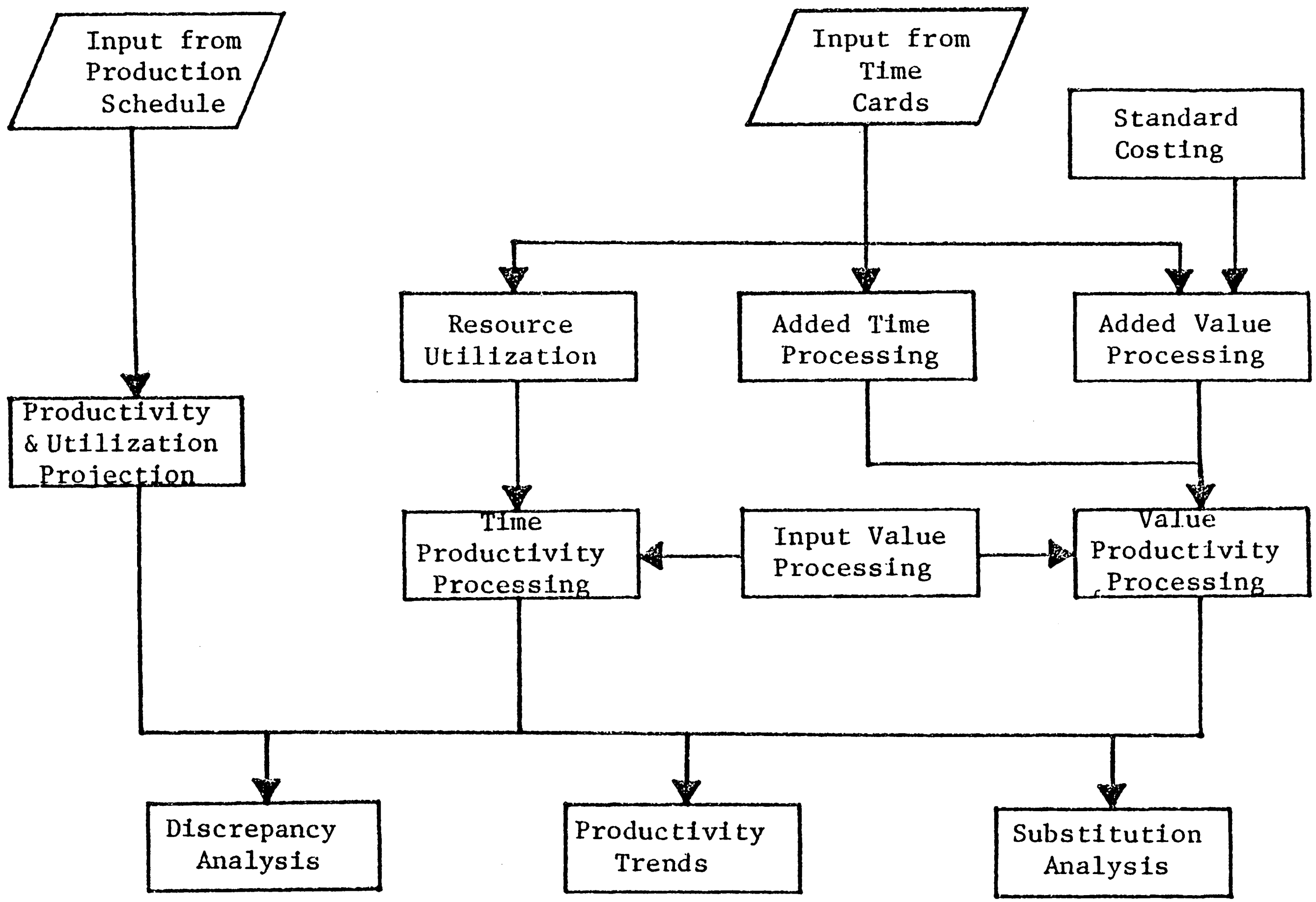
APPENDIXES



Appendix A. Subsystems of PMS

Appendix B. File Definitions

```
P/* DEFINITION OF EMPLOYEE FILE
EMP      RC
EMP      FDEMP        BF  40
EMP      LOEMP-NO          1   9C1
EMP      LOLB-CD          10   4C
EMP      L1LB-CD                                         LABOR
EMP      L2LB-CD                                         CATEGORY
EMP      L3LB-CD                                         CODE
EMP      LOPAY-BASE       14   7Z Y2
EMP      L1PAY-BASE                                      BASE YR
EMP      L2PAY-BASE                                      PAY RATE
EMP      LOPAY-CURR       21   7Z Y2
EMP      L1PAY-CURR                                      CURRENT
EMP      L2PAY-CURR                                      PAY RATE

P/* DEFINITION OF ENERGY FILE
ENERGY   RC
ENERGY   FDENERGY     BF  18
ENERGY   LOENG-CD          1   4C1
ENERGY   L1ENG-CD                                        ENERGY
ENERGY   L2ENG-CD                                        CODE
ENERGY   LOUM              5   2C
ENERGY   L1UM                                            UNIT OF
ENERGY   L2UM                                            MEASURE
ENERGY   LOPR-BASE         7   6Z Y3      $
ENERGY   L1PR-BASE                                       BASE
ENERGY   L2PR-BASE                                       PRICE
ENERGY   LOPR-CURR        13   6Z Y3      $
ENERGY   L1PR-CURR                                       CURRENT
ENERGY   L2PR-CURR                                       PRICE
```

```
P/* DEFINITION OF EQUIPMENT FILE
EQ         RC
EQ         FDEQ         BF  40
EQ         LOEQ-NO           1   6C1
EQ         L1EQ-NO                                     EQUIPMNT
EQ         L2EQ-NO                                     NUMBER
EQ         LOLEASE-YR        7   7Z           $
EQ         L1LEASE-YR                                  LEASE
EQ         L2LEASE-YR                                  VALUE
EQ         L3LEASE-YR                                  PER YEAR
EQ         LOENG-CD         14   4C
EQ         L1ENG-CD                                    ENERGY
EQ         L2ENG-CD                                    CODE
EQ         LOCON-H          18   5Z Y2
EQ         L1CON-H                                     CONSUMP-
EQ         L2CON-H                                     TION PER
EQ         L3CON-H                                     HOUR
EQ         LOWGT-IX         23   4Z Y1
EQ         L1WGT-IX                                    IMPACT
EQ         L2WGT-IX                                    WEIGHT
EQ         L3WGT-IX                                    INDEX

P/* DEFINITION OF SUBFILE FILEO
FILEO      RC
FILEO      FDFILEO      BF  50
FILEO      LOENG-CD          1   4C1
FILEO      LOGP-NO           5   9C
FILEO      LOENERGY         14   9Z Y2
```

```
P/* DEFINITION OF SUBFILE FILE1
FILE1    RC
FILE1    FDFILE1     BF   50
FILE1    L0MC-NO            1   6C1
FILE1    L1MC-NO                                  MC NO
FILE1    L0GP-NO            7   9C
FILE1    L1GP-NO                                  GP NO
FILE1    L0COST            16   9Z Y2
FILE1    L1COST                                   COST

P/* DEFINITION OF SUBFILE FILE2
FILE2    RC
FILE2    FDFILE2     BF   50
FILE2    L0EMP-NO           1   9C1
FILE2    L1EMP-NO                                 EMP NO
FILE2    L0GP-NO           10   9C
FILE2    L1GP-NO                                  GP NO
FILE2    L0COST            19   9Z Y2
FILE2    L1COST                                   COST

P/* DEFINITION OF SUBFILE FILE3
FILE3    RC
FILE3    FDFILE3     BF   50
FILE3    L0EQ-NO            1   6C1
FILE3    L1EQ-NO                                  EQ NO
FILE3    L0GP-NO            7   9C
FILE3    L1GP-NO                                  GP NO
FILE3    L0COST            16   9Z Y2
FILE3    L1COST                                   COST
```

```
P/* DEFINITION OF SUBFILE FILE4
FILE4    RC
FILE4    FDFILE4     BF   50
FILE4    LOKEY              1  12C1
FILE4    LOVALUE           13  12Z  Y2

P/* DEFINITION OF SUBFILE FILE5
FILE5    RC
FILE5    FDFILE5     BF   50
FILE5    LOSUB-GP           1   9C1
FILE5    L1SUB-GP                                   SUB GP
FILE5    LOFLAG            10   1C
FILE5    L1FLAG                                     FLAG

P/* DEFINITION OF SUBFILE FILE6
FILE6    RC
FILE6    FDFILE6     BF   80
FILE6    LOKEY              1   6Z1        Z
FILE6    LOQ-B              7   7Z   2
FILE6    LOQ-1             14   7Z   2
FILE6    LOQ-2             21   7Z   2
FILE6    LOQ-3             28   7Z   2
FILE6    LOQ-4             35   7Z   2
FILE6    LOQ-5             42   7Z   2
FILE6    LOQ-6             49   7Z   2
FILE6    LOQ-7             56   7Z   2
FILE6    LOQ-8             63   7Z   2
FILE6    LOWK-UT           70   9C
```

```
P/* DEFINITION OF SUBFILE FILE7
FILE7    RC
FILE7    FDFILE7     BF  80
FILE7    LOKEY             1   6C1
FILE7    LOQ-B             7   7Z   2
FILE7    LOQ-1            14   7Z   2
FILE7    LOQ-2            21   7Z   2
FILE7    LOQ-3            28   7Z   2
FILE7    LOQ-4            35   7Z   2
FILE7    LOQ-5            42   7Z   2
FILE7    LOQ-6            49   7Z   2
FILE7    LOQ-7            56   7Z   2
FILE7    LOQ-8            63   7Z   2

P/* DEFINITION OF SUBFILE FILE8
FILE8    RC
FILE8    FDFILE8     BF  50
FILE8    LOMC-NO           1   6C1
FILE8    LOEMP-NO          7   9C
FILE8    LOGP-NO          16   9C

P/* DEFINITION OF SUBFILE FILE9
FILE9    RC
FILE9    FDFILE9     BF  12
FILE9    LONO              1   6Z1         Z
FILE9    LINO                                      OP NO
FILE9    LOMT-NO           7   6Z          Z
FILE9    LIMT-NO                                   MANT NO
```

```
P/* DEFINITION OF SUBFILE FILE10
FILE10   RC
FILE10   FDFILE10    BF   50
FILE10   L0NO                  1 11C1
FILE10   L1NO                                         INVENTRY
FILE10   L2NO                                         NO
FILE10   L0Q                  12   7Z   3
FILE10   L1Q                                          QUANTITY
FILE10   L2Q                                          USED

P/* DEFINITION OF SUBFILE FILE11
FILE11   RC
FILE11   FDFILE11    BF   80
FILE11   L0EMP-NO              1   9C1
FILE11   L0Q-B                10   7Z   2
FILE11   L0Q-1                17   7Z   2
FILE11   L0Q-2                24   7Z   2
FILE11   L0Q-3                31   7Z   2
FILE11   L0Q-4                38   7Z   2
FILE11   L0Q-5                45   7Z   2
FILE11   L0Q-6                52   7Z   2
FILE11   L0Q-7                59   7Z   2
FILE11   L0Q-8                66   7Z   2

P/* DEFINITION OF SUBFILE FILE12
FILE12   RC
FILE12   FDFILE12    BF   50
FILE12   L0OP-NO               1   6Z1        Z
FILE12   L1OP-NO                                      OP NO
```

```
FILE12  L0CODE          7   1C
FILE12  L1CODE                              JOB CODE
FILE12  L0WK-NO         8   9C
FILE12  L1WK-NO                             WORKING
FILE12  L2WK-NO                             UNIT NO
FILE12  L0JOB-NO       17   5C
FILE12  L1JOB-NO                            JOB NO
FILE12  L0Q-FSH        22   7Z Y3
FILE12  L1Q-FSH                             QUANTITY
FILE12  L2Q-FSH                             FINISHED
FILE12  L0DATE         29   5Z        Z
FILE12  L1DATE                              JULIAN

P/* DEFINITION OF SUBFILE FILE13
FILE13  RC
FILE13  FDFILE13    BF  50
FILE13  L0WK-NO         1   9C1
FILE13  L1WK-NO                             WORKING
FILE13  L2WK-NO                             UNIT NO
FILE13  L0JOB-NO       10   5C
FILE13  L1JOB-NO                            JOB NO
FILE13  L0SUB-T        15   7Z Y3
FILE13  L1SUB-T                             ST TIME
FILE13  L0SUB-LB       22   7Z Y3
FILE13  L1SUB-LB                            LB TIME
FILE13  L0SUB-MC       29   7Z Y3
FILE13  L1SUB-MC                            MC TIME
FILE13  L0DATE         36   5Z        Z
FILE13  L1DATE                              JULIAN
```

```
P/* DEFINITION OF SUBFILE FILE14
FILE14  RC
FILE14  FDFILE14    BF  50
FILE14  LOGP-NO            1  9C1
FILE14  LOMC-NO           10  6C
FILE14  LOEMP-NO          16  9C
FILE14  LOEQ-NO           25  6C
FILE14  LOSUB-GP          31  9C
FILE14  LOOH              40  9Z  2


P/* DEFINITION OF SUBFILE FILE15
FILE15  RC
FILE15  FDFILE15    BF  50
FILE15  LOWK-NO            1  9C1
FILE15  LOJOB-NO          10  5C
FILE15  LOSUB-MIN         15  7Z  2


P/* DEFINITION OF SUBFILE FILE16
FILE16  RC
FILE16  FDFILE16    BF  50
FILE16  LOID               1  9C1
FILE16  L1ID                                    WORKING
FILE16  L2ID                                    UNIT
FILE16  LOMC-NO           10  6C
FILE16  LOEMP-NO          16  9C
FILE16  LOLB              25  7Z  3
FILE16  LOMC              32  7Z  3


P/* DEFINITION OF SUBFILE FILE17
```

```
FILE17  RC
FILE17  FDFILE17    BF  60
FILE17  L0ID             1   9C1
FILE17  L1ID                                      WORKING
FILE17  L2ID                                      UNIT
FILE17  L0T             10   7Z   3
FILE17  L1T                                       TOTAL
FILE17  L2T                                       TIME
FILE17  L0T-IX          17   5Z   2
FILE17  L1T-IX                                    WK UNIT
FILE17  L2T-IX                                    PTY(%)
FILE17  L0LB            22   7Z   3
FILE17  L1LB                                      LABOR
FILE17  L2LB                                      TIME
FILE17  L0LB-IX         29   5Z   2
FILE17  L1LB-IX                                   LABOR
FILE17  L2LB-IX                                   PTY(%)
FILE17  L0MC            34   7Z   3
FILE17  L1MC                                      MACHINE
FILE17  L2MC                                      TIME
FILE17  L0MC-IX         41   5Z   2
FILE17  L1MC-IX                                   MACHINE
FILE17  L2MC-IX                                   PTY(%)
FILE17  L0DATE          46   5Z         Z
FILE17  L1DATE                                    JULIAN-
FILE17  L2DATE                                    DATE
FILE17  L0LEVEL         51   1C
FILE17  L1LEVEL                                   WK UNIT
FILE17  L2LEVEL                                   LEVEL

P/* DEFINITION OF SUBFILE FILE18
```

```
FILE18  RC
FILE18  FDFILE18    BF  50
FILE18  L0GP-NO          1   9C
FILE18  L1GP-NO                                   GROUP NO
FILE18  L0LEVEL         10   1C
FILE18  L1LEVEL                                   GP LEVEL
FILE18  L0FACTOR        11   9C1
FILE18  L1FACTOR                                  FACTOR
FILE18  L0INPUT         20   7Z   3
FILE18  L1INPUT                                   INPUT
FILE18  L0PTY           27   5Z   2
FILE18  L1PTY                                     PTY (%)

P/* DEFINITION OF SUBFILE FILE19
FILE19  RC
FILE19  FDFILE19    BF  50
FILE19  L0GP-NO          1   9C
FILE19  L0LEVEL         10   1C
FILE19  L0FACTOR        11   9C1
FILE19  L0INPUT         20   9Z   2
FILE19  L0PTY           29   5Z   2

P/* DEFINITION OF SUBFILE FILE20
FILE20  RC
FILE20  FDFILE20    BF  50
FILE20  L0GP-NO          1   9C
FILE20  L0LEVEL         10   1C
FILE20  L0FACTOR        11   9C1
FILE20  L0INPUT         20   9Z   2
FILE20  L0PTY           29   5Z   2
```

```
P/* DEFINITION OF SUBFILE FILE21
FILE21   RC
FILE21   FDFILE21     BF   50
FILE21   LOGP-NO             1   9C
FILE21   LOLEVEL            10   1C
FILE21   LOFACTOR           11   9C1
FILE21   LOINPUT            20   9Z   2
FILE21   LOPTY              29   5Z   2

P/* DEFINITION OF SUBFILE FILE22
FILE22   RC
FILE22   FDFILE22     BF   50
FILE22   LOGP-NO             1   9C1
FILE22   LOLEVEL            10   1C
FILE22   LOOH               11   9Z   2

P/* DEFINITION OF SUBFILE FILE23
FILE23   RC
FILE23   FDFILE23     BF   20
FILE23   LOITEM              1 11C1
FILE23   L1ITEM                                    ITEM
FILE23   LOQTY              12   6Z   3
FILE23   L1QTY                                     QUANTITY

P/* DEFINITION OF SUBFILE FILE24
FILE24   RC
FILE24   FDFILE24     BF   20
```

```
FILE24  LOITEM             1 11C1
FILE24  LOQTY             12  6Z  3


P/* DEFINITION OF SUBFILE FILE25
FILE25  RC
FILE25  FDFILE25   BF  30
FILE25  LOITEM             1 15C1
FILE25  L1ITEM                                    COST
FILE25  L2ITEM                                    CATEGORY
FILE25  LOCOST            16  7Z  3
FILE25  L1COST                                    COST


P/* DEFINITION OF SUBFILE FILE26
FILE26  RC
FILE26  FDFILE26   BF  20
FILE26  LOTL-CD            1  5C1
FILE26  LOST-UT            6  4Z  2
FILE26  LOSK-CD           10  4C
FILE26  LOMC-NO           14  6C


P/* DEFINITION OF SUBFILE FILE27
FILE27  RC
FILE27  FDFILE27   BF  20
FILE27  LOENG-CD           1  4C1
FILE27  LOCON              5  7Z  2


P/* DEFINITION OF SUBFILE FILE28
FILE28  RC
```

```
FILE28  FDFILE28    BF  50
FILE28  LOITEM             1 11C1
FILE28  L1ITEM                                        ITEM NO
FILE28  LOWK-UT           12   9C
FILE28  L1WK-UT                                       WK UNIT
FILE28  LOQTY             21   7Z Y3
FILE28  L1QTY                                         QUANTITY
FILE28  LODATE            28   5Z          Z
FILE28  L1DATE                                        JULIAN

P/* DEFINITION OF SUBFILE FILE29
FILE29  RC
FILE29  FDFILE29    BF  50
FILE29  LOITEM             1 11C1
FILE29  L1ITEM                                        ITEM NO
FILE29  LOCOST            12   7Z Y3
FILE29  L1COST                                        COST
FILE29  LOWK-UT           19   9C
FILE29  L1WK-UT                                       WK UNIT
FILE29  LODATE            28   5Z          Z
FILE29  L1DATE                                        JULIAN

P/* DEFINITION OF SUBFILE FILE30
FILE30  RC
FILE30  FDFILE30    BF  50
FILE30  LOWK-UT            1   9C1
FILE30  L1WK-UT                                       WK UNIT
FILE30  LOVADD            10   7Z Y2
FILE30  L1VADD                                        ADD VALUE
FILE30  LODATE            17   5Z          Z
```

```
FILE30  L1DATE                                          JULIAN


P/* DEFINITION OF SUBFILE FILE31
FILE31  RC
FILE31  FDFILE31   BF  30
FILE31  LOOP-NO          1  6Z1         Z
FILE31  L1OP-NO                                         CP NO
FILE31  LOITEM           7 11C
FILE31  L1ITEM                                          ITEM NO
FILE31  LOST-UT         18  4Z Y2
FILE31  L1ST-UT                                         ST TIME


P/* DEFINITION OF SUBFILE FILE32
FILE32  RC
FILE32  FDFILE32   BF  30
FILE32  LOITEM-1         1 11C1
FILE32  L1ITEM-1                                        ITEM NO
FILE32  LOITEM-2        12 11C
FILE32  L1ITEM-2                                        ITEM NO


P/* DEFINITION OF SUBFILE FILE33
FILE33  RC
FILE33  FDFILE33   BF  80
FILE33  LOGP-NO          1  9C1
FILE33  L1GP-NO                                         GP NO
FILE33  LOLABOR         10  9Z Y2
FILE33  L1LABOR                                         LABOR
FILE33  L2LABOR                                         INPUT
FILE33  LOCAPITAL       19  9Z Y2
```

```
FILE33   L1CAPITAL                          CAPITAL
FILE33   L2CAPITAL                          INPUT
FILE33   L0ENERGY        28   9Z Y2
FILE33   L1ENERGY                           ENERGY
FILE33   L2ENERGY                           INPUT
FILE33   L0MATERIAL      37   9Z Y2
FILE33   L1MATERIAL                         MATERIAL
FILE33   L2MATERIAL                         INPUT
FILE33   L0TOOL          46   9Z Y2
FILE33   L1TOOL                             TOOL
FILE33   L2TOOL                             INPUT
FILE33   L0SUB-GP        55   9C
FILE33   L1SUB-GP                           SUB GP
FILE33   L2SUB-GP                           NO

P/* DEFINITION OF SUBFILE FILE34
FILE34   RC
FILE34   FDFILE34    BF  80
FILE34   L0MC-NO          1   6C1
FILE34   L0Q-B            7   7Z  2
FILE34   L0Q-1           14   7Z  2
FILE34   L0Q-2           21   7Z  2
FILE34   L0Q-3           28   7Z  2
FILE34   L0Q-4           35   7Z  2
FILE34   L0Q-5           42   7Z  2
FILE34   L0Q-6           49   7Z  2
FILE34   L0Q-7           56   7Z  2
FILE34   L0Q-8           63   7Z  2

P/* DEFINITION OF SUBFILE FILE35
```

```
FILE35  RC
FILE35  FDFILE35    BF   50
FILE35  LOMC-NO           1   6C1
FILE35  L1MC-NO                                     MC NO
FILE35  LOOP-TIME         7   7Z   3
FILE35  L1OP-TIME                                   OP TIME
FILE35  LOUF             14   7Z   3
FILE35  L1UF                                        UTZTN

P/* DEFINITION OF SUBFILE FILE36
FILE36  RC
FILE36  FDFILE36    BF   50
FILE36  LOMC-NO           1   6C1
FILE36  L1MC-NO                                     MC NO
FILE36  LOOP-TIME         7   7Z   3
FILE36  L1OP-TIME                                   OP TIME

P/* DEFINITION OF SUBFILE FILE37
FILE37  RC
FILE37  FDFILE37    BF   50
FILE37  LOEMP-NO          1   9C1
FILE37  L1EMP-NO                                    EMP NO
FILE37  LOOP-TIME        10   7Z   3
FILE37  L1OP-TIME                                   OP TIME
FILE37  LOUF             17   7Z   3
FILE37  L1UF                                        UTZTN

P/* DEFINITION OF SUBFILE FILE123
FILE123 RC
```

```
FILE123 FDFILE123   BF   30
FILE123 LOITEM              1 11C1
FILE123 L1ITEM                                          ITEM
FILE123 LOQTY              12   6Z   3
FILE123 L1QTY                                           QUANTITY
FILE123 LOINV-NO           18 11C
FILE123 L1INV-NO                                        INV NO

P/* DEFINITION OF SUBFILE FILE124
FILE124 RC
FILE124 FDFILE124   BF   30
FILE124 LOITEM              1 11C1
FILE124 LOQTY              12   6Z   3
FILE124 LOINV-NO           18 11C

P/* DEFINITION OF SUBFILE FILE125
FILE125 RC
FILE125 FDFILE125   BF   40
FILE125 LOITEM              1 15C
FILE125 L1ITEM                                          COST
FILE125 L2ITEM                                          CATEGORY
FILE125 LOCOST             16   7Z   3
FILE125 L1COST                                          COST
FILE125 LOINV-NO           23 11C1
FILE125 L1INV-NO                                        INV NO

P/* DEFINITION OF SUBFILE FILE126
FILE126 RC
FILE126 FDFILE126   BF   30
```

```
FILE126 LOTL-CD          1  5C1
FILE126 LOST-UT          6  4Z  2
FILE126 LOSK-CD         10  4C
FILE126 LOMC-NO         14  6C
FILE126 LOINV-NO        20 11C


P/* DEFINITION OF SUBFILE FILE127
FILE127 RC
FILE127 FDFILE127  BF  30
FILE127 LOENG-CD         1  4C1
FILE127 LOCON            5  7Z  2
FILE127 LOINV-NO        12 11C


P/* DEFINITION OF ORGANIZATION STRUCTURE FILE
GP      RC
GP      FDGP      AV        2000
GP      LOGP-NO    11   1  9C1
GP      L1GP-NO                                  GROUP NO
GP      LOLEVEL    11  10  1C
GP      L1LEVEL                                  GP LEVEL
GP      LOGP-C-2   11  11  2Z     2    Z
GP      LOGP-C-3   11  13  2Z     3    Z
GP      LOGP-C-4   11  15  2Z     4    Z
GP      LOGP-C-5   11  17  2Z     5    Z
GP      LOGP-C-6   11  19  2Z     6    Z
GP      LOMC-NO    22   1  6C1
GP      L1MC-NO                                  MACHINE
GP      L2MC-NO                                  NO
GP      LOEMP-NO   32   1  9C1
GP      L1EMP-NO                                 EMPLOYEE
```

```
GP       L2EMP-NO                                        NO
GP       L0EQ-NO       42    1   6C1
GP       L1EQ-NO                                         EQMT NO
GP       L0SUB-GP      52    1   9C1
GP       L1SUB-GP                                        SUB
GP       L2SUB-GP                                        GROUP NO
GP       L0OH          62    1   9Z1 2        $
GP       L1OH                                            OVERHEAD

P/* DEFINITION OF INVENTORY FILE
INV      RC
INV      FDINV        BF   40
INV      L0INV-NO            1 11C1
INV      L1INV-NO                                        INVENTRY
INV      L2INV-NO                                        NO
INV      L0UM               12   2C
INV      L1UM                                            UNIT OF
INV      L2UM                                            MEASURE
INV      L0C-BASE           14   7Z   2       $
INV      L1C-BASE                                        BASE
INV      L2C-BASE                                        COST
INV      L0C-CURR           21   7Z   2       $
INV      L1C-CURR                                        CURRENT
INV      L2C-CURR                                        COST
INV      L0ST-UT            28   6Z Y2
INV      L1ST-UT                                         STANDARD
INV      L2ST-UT                                         UP TIME

P/* DEFINITION OF TIME CARDS FOR SERVICES
JOB1     RC
```

```
JOB1      FDJOB1      BF   50
JOB1      L0WK-NO        1   9C1
JOB1      L1WK-NO                                WORKING
JOB1      L2WK-NO                                UNIT NO
JOB1      L0JOB-NO      10   5C
JOB1      L1JOB-NO                               JOB NO
JOB1      L0DATE        15   5Z           Z
JOB1      L1DATE                                 JULIAN
JOB1      L2DATE                                 DATE
JOB1      L0TIME-I      20   8C
JOB1      L1TIME-I                               TIME IN
JOB1      L2TIME-I                               H,M,S
JOB1      L0H-I         20   2Z           Z
JOB1      L1H-I                                  HOUR
JOB1      L0M-I         23   2Z           Z
JOB1      L1M-I                                  MINUTE
JOB1      L0S-I         26   2Z           Z
JOB1      L1S-I                                  SECOND
JOB1      L0TIME-O      28   8C
JOB1      L1TIME-O                               TIME OUT
JOB1      L2TIME-O                               H,M,S
JOB1      L0H-O         28   2Z           Z
JOB1      L1H-O                                  HOUR
JOB1      L0M-O         31   2Z           Z
JOB1      L1M-O                                  MINUTE
JOB1      L0S-O         34   2Z           Z
JOB1      L1S-O                                  SECOND

P/* DEFINITION OF TIME CARDS FOR NON-STANDARD PRODUCTS
JOB2      RC
JOB2      FDJOB2      BF   50
```

```
JOB2     L0WK-NO         1  9C1
JOB2     L1WK-NO                                  WORKING
JOB2     L2WK-NO                                  UNIT NO
JOB2     L0JOB-NO       10  5C
JOB2     L1JOB-NO                                 JOB NO
JOB2     L0ITEM-O       15 11C
JOB2     L1ITEM-O                                 ITEM OUT
JOB2     L0ITEM-I       26 11C
JOB2     L1ITEM-I                                 ITEM IN
JOB2     L0Q-FSH        37  7Z Y3
JOB2     L1Q-FSH                                  QUANTITY
JOB2     L2Q-FSH                                  FINISH
JOB2     L0DATE         44  5Z          Z
JOB2     L1DATE                                   JULIAN
JOB2     L2DATE                                   DATE

P/* DEFINITION OF TIME CARDS FOR STANDARD PRODUCTS
JOB3     RC
JOB3     FDJOB3     BF  50
JOB3     L0WK-NO         1  9C1
JOB3     L1WK-NO                                  WK UNIT
JOB3     L0JOB-NO       10  5C
JOB3     L1JOB-NO                                 JOB NO
JOB3     L0ITEM-NO      15 11C
JOB3     L1ITEM-NO                                ITEM NO
JOB3     L0Q-FSH        26  7Z Y3
JOB3     L1Q-FSH                                  QUANTITY
JOB3     L2Q-FSH                                  COMPLETE
JOB3     L0DATE         33  5Z          Z
JOB3     L1DATE                                   JULIAN
JOB3     L2DATE                                   DATE
```

```
JOB3      LOTIME          38   8C
JOB3      L1TIME                                  HOUR MIN
JOB3      L2TIME                                  SECOND
JOB3      LOT-HR          38   2Z          Z
JOB3      L1T-HR                                  HOUR
JOB3      LOT-MIN         41   2Z          Z
JOB3      L1T-MIN                                 MINUTE
JOB3      LOT-SEC         44   2Z          Z
JOB3      L1T-SEC                                 SECOND


P/* DEFINITION OF MACHINE FILE
MC        RC
MC        FDMC        BF  40
MC        LOMC-NO          1   6C1
MC        L1MC-NO                                 MACHINE
MC        L2MC-NO                                 NUMBER
MC        LOLEASE-YR       7   7Z          $
MC        L1LEASE-YR                              LEASE
MC        L2LEASE-YR                              VALUE
MC        L3LEASE-YR                              PER YEAR
MC        LOENG-CD        14   4C
MC        L1ENG-CD                                ENERGY
MC        L2ENG-CD                                CODE
MC        LOCON-H         18   5Z Y4
MC        L1CON-H                                 CONSUMP-
MC        L2CON-H                                 TION PER
MC        L3CON-H                                 HOUR
MC        LOWGT-IX        23   4Z Y1
MC        L1WGT-IX                                IMPACT
MC        L2WGT-IX                                WEIGHT
MC        L3WGT-IX                                INDEX
```

```
P/* DEFINITION OF OPERATION FILE
OP       RC
OP       FDOP         AF  50
OP       LOOP-NO           1   6Z1         Z
OP       L1OP-NO                                  OP NO
OP       LOTL-CD           7   5C
OP       L1TL-CD                                  TOOL
OP       L2TL-CD                                  CODE
OP       LOST-UT          12   4Z Y2
OP       L1ST-UT                                  STANDARD
OP       L2ST-UT                                  TIME
OP       LOMIN-UT         16   4Z Y2
OP       L1MIN-UT                                 MINIMUM
OP       L2MIN-UT                                 TIME
OP       LOST-LB          20   4Z Y2
OP       L1ST-LB                                  STANDRAD
OP       L2ST-LB                                  LB TIME
OP       LOSK-CD          24   4C
OP       L1SK-CD                                  SKILL
OP       L2SK-CD                                  CODE
OP       LOST-MC          28   4Z Y2
OP       L1ST-MC                                  STANDRAD
OP       L2ST-MC                                  MC TIME
OP       LOMC-NO          32   6C
OP       L1MC-NO                                  MACHINE
OP       L2MC-NO                                  NO

P/* DEFINITION OF OPERATION STRUCTURE FILE
OPS      RC
```

```
OPS       FDOPS        AV         2000
OPS       LOOP-NO-1     11    1   6Z1          Z
OPS       L1OP-NO-1                                      OP NO-1
OPS       LOOP-C-1      11    7   2Z      2    Z
OPS       LOOP-NO-2     22    1   6Z1          Z
OPS       L1OP-NO-2                                      OP NO-2
OPS       LOOP-C-2      22    7   2Z      3    Z
OPS       LOOP-NO-3     33    1   6Z1          Z
OPS       L1OP-NO-3                                      OP NO-3
OPS       LOOP-C-3      33    7   2Z      4    Z
OPS       LOOP-NO-4     44    1   6Z1          Z
OPS       L1OP-NO-4                                      OP NO-4


P/* DEFINITION OF SUBFILE OP100
OP100     RC
OP100     FDOP100      AF  50
OP100     LOOP-NO             1   6Z1          Z
OP100     L1OP-NO                                        OP NO
OP100     L0INV-NO            7 11C
OP100     L1INV-NO                                       INV NO


P/* DEFINITION OF PRODUCT STRUCTURE FILE
PS        RC
PS        FDPS         BV2000
PS        L0ITEM-P      11    1 11C1
PS        L1ITEM-P                                       PARENT
PS        L0ITEM-C      11   12   2Z      2
PS        L0ITEM-S      22    1 11C1
PS        L1ITEM-S                                       CHILD
PS        L0QTY         22   12   6Z  3
```

```
PS      L1QTY                                       QUANTITY
PS      LOOP-NO      22  18  6Z          Z
PS      L1OP-NO                                     OP NO
PS      LOWK-UT      22  24  9C
PS      L1WK-UT                                     WK UNIT


P/* DEFINITION OF PRODUCTION SCHEDULE FILE
SCH     RC
SCH     FDSCH      AF  80
SCH     LOITEM-NO        1 11C1
SCH     L1ITEM-NO                                   ITEM NO
SCH     LOQ-B           12  7Z Y2
SCH     L1Q-B                                       BACKLOG
SCH     L2Q-B                                       DEMAND
SCH     LOQ-1           19  7Z Y2
SCH     L1Q-1                                       1ST WK
SCH     L2Q-1                                       DEMAND
SCH     LOQ-2           26  7Z Y2
SCH     L1Q-2                                       2ND WK
SCH     L2Q-2                                       DEMAND
SCH     LOQ-3           33  7Z Y2
SCH     L1Q-3                                       3RD WK
SCH     L2Q-3                                       DEMAND
SCH     LOQ-4           40  7Z Y2
SCH     L1Q-4                                       4TH WK
SCH     L2Q-4                                       DEMAND
SCH     LOQ-5           47  7Z Y2
SCH     L1Q-5                                       5TH WK
SCH     L2Q-5                                       DEMAND
SCH     LOQ-6           54  7Z Y2
SCH     L1Q-6                                       6TH WK
```

```
SCH     L2Q-6                                      DEMAND
SCH     L0Q-7          61   7Z Y2
SCH     L1Q-7                                      7TH WK
SCH     L2Q-7                                      DEMAND
SCH     L0Q-8          68   7Z Y2
SCH     L1Q-8                                      8TH WK
SCH     L2Q-8                                      DEMAND

P/* DEFINITION OF LABOR SKILL FILE
SK      RC
SK      FDSK        AF   50
SK      L0SK-CD             1   4C1
SK      L1SK-CD                                    SKILL
SK      L2SK-CD                                    CODE
SK      L0PAY-BASE          5   7Z   2
SK      L1PAY-BASE                                 PAY RATE
SK      L2PAY-BASE                                 BASE YR
SK      L0PAY-CURR         12   7Z   2
SK      L1PAY-CURR                                 PAY RATE
SK      L2PAY-CURR                                 CURRENT

P/* DEFINITION OF TOOL FILE
TL      RC
TL      FDTL        BF   20
TL      L0TL-CD             1   5C1
TL      L1TL-CD                                    TOOL
TL      L2TL-CD                                    CODE
TL      L0LEASE-YR          6   7Z          $
TL      L1LEASE-YR                                 COST
TL      L2LEASE-YR                                 PER YEAR
```

```
TL        L0WGT-IX        13   4Z Y1
TL        L1WGT-IX                          WEIGHT
TL        L2WGT-IX                          INDEX
```

Appendix C. Data for Master Files

P/* EMP DATA (DATA OF EMPLOYEE FILE)

08/22/82 EMPLOYEE FILE

EMPLOYEE NO	LABOR CODE	BASE PAY RATE($)	CURRENT PAY RATE($)
007-82-4299	MCF5	16.78	19.21
009-23-1567	PRS3	14.36	16.35
011-29-4234	ASS1	5.79	8.86
012-03-5568	S 3	15,090.00	16,954.50
012-92-8824	S 2	19,050.70	25,778.15
019-29-7862	REC3	12.51	13.55
039-37-4153	PRS1	8.25	10.62
107-29-0088	S 3	14,539.00	18,845.55
123-39-2182	ASS1	6.54	8.56
126-32-0076	BLS3	13.65	17.35
156-62-1111	THP1	6.54	7.32
156-72-3308	PRS3	12.12	15.25
158-28-8122	BLS1	5.96	8.85
162-06-2612	S 2	28,500.00	31,500.00
167-25-4312	S 3	17,460.00	19,500.00
176-32-0188	PRS1	8.55	10.15
178-21-5623	S 1	32,500.00	43,510.00
178-69-7852	ASS3	12.31	15.34
192-92-2376	BLS1	5.60	8.30
196-96-6666	ASS3	8.76	10.53
198-88-2525	CRF3	10.32	13.21
206-09-0184	S 3	13,490.00	17,880.00
209-24-7230	PRS1	6.75	11.55
218-19-0233	DRI1	10.90	12.30
219-00-5120	ASS1	5.30	6.95
219-04-5262	PRS1	7.65	9.56

219-67-4569	MCF1	6.54	8.36
246-42-0188	S 3	18,500.00	21,205.00
256-36-4253	THP1	5.45	7.56
269-39-5214	S 3	12,321.00	15,735.00
279-02-6202	BLS1	7.69	9.95
313-19-0299	S 2	27,650.00	30,300.00
314-90-0191	ASS3	10.27	12.55
321-18-7237	BLS3	15.48	18.66
323-03-3452	BLS1	7.65	10.05
327-50-0001	MHI5	19.87	21.36
333-29-0160	S 3	14,320.00	16,535.55
336-24-5123	DRI3	12.30	14.30
346-56-2819	S 3	18,764.00	20,200.00
349-27-0999	S 3	15,490.00	17,755.00
382-52-2536	PUN1	8.76	10.50
423-99-7268	MCF3	11.29	13.95
427-29-3614	PRS3	15.65	17.75
444-14-2468	MCF1	8.55	9.50
453-56-3236	S 1	31,250.00	33,500.00
456-78-2156	THP3	8.75	9.82
467-26-3234	MCF1	6.95	9.50
509-09-1767	MHI5	17.86	20.35
513-33-0122	MCF1	8.76	9.95
513-39-7467	DRI1	6.57	8.88
525-26-7654	MHI3	12.01	13.55
542-43-7329	PRS1	8.34	10.36
555-19-7767	REC1	6.72	10.05
630-00-1256	BLS3	14.32	15.60
666-90-2354	BLS3	12.01	14.26
732-56-8818	S 3	21,000.00	22,500.00
736-77-4236	CRF1	5.55	6.55
737-01-2854	PUN3	10.29	13.55

762-34-0088	DRI5	17.86	21.40
782-89-0108	MCF1	6.75	8.36

P/* ENERGY DATA (INPUT DATA OF ENERGY FILE)
08/22/82 ENERGY FILE

ENERGY CODE	UNIT OF MEASURE	BASE PRICE($)	CURRENT PRICE($)
GAS	LB	.470	.780
ELEC	KW	.035	.052
HYDG	LB	2.740	3.940
OXYG	LB	1.360	2.020
PETA	GL	.920	1.240
PETB	GL	.810	1.190

P/* EQ DATA (INPUT DAT OF EQUIPMENT FILE)
08/22/82 EQUIPMENT FILE

EQUIPMNT NO	YEARLY VALUE($)	ENERGY CODE	HOURLY COMSUMPTION	WEIGHT INDES(%)
BG01	13,200	ELEC	9.56	25.0
BG05	9,000	ELEC	10.26	25.0
BL30	25,000	ELEC	19.82	25.0
CM09	150,000	ELEC	37.95	25.0
MK03	25,300	ELEC	13.20	25.0
MK15	18,150	ELEC	9.50	25.0
MT09	876		.00	25.0
MT12	1,245	ELEC	7.88	25.0

MT25	1,235	ELEC	8.35	25.0
MT41	980	OXYG	1.26	25.0
PB07	1,500	ELEC	4.35	25.0
TK01	3,500	PETA	7.86	25.0
TK05	3,600	PETA	4.59	25.0
TK19	3,595	PETB	12.62	25.0
WH01	12,000	ELEC	7.86	25.0
WH03	19,000	GAS	3.25	25.0

P/* GP DATA (INPUT DATA OF ORGANIZATION STRUCTURE)
08/22/82 MACHINE GROUPING

WORK UNIT	LEVEL	MACHINE
ASSEMBLY1	2	77M511
ASSEMBLY2	2	71X773
BLS03	1	81L783
BLS07	1	81L833
BLS07	1	81L844
BLS11	1	81L933
BLS12	1	81L991
BLS15	1	81L983
BLS17	1	81L732
BLS19	1	81L500
BLS23	1	81L713
BLS23	1	81L727
BLS33	1	81L527
BLS37	1	81L526
BLS43	1	81L427
CNT05	1	77X256
CNT12	1	77X323

FINISHING	2	74A532
MC09	1	81L633
MC15	1	81L855
MC16	1	81L437
MC17	1	81L536
MC18	1	81L993
MC21	1	81L693
MC23	1	81L419
MC29	1	81L987
MC45	1	81L531
MC45	1	81L559
MC45	1	81L997
MISNOUS	2	75X457
POLE06	1	77L231
POLE15	1	77L321
PRS09	1	81L923
PRS12	1	81L635
PRS12	1	81L883
PRS14	1	81L691
PRS14	1	81L995
PRS15	1	81L423
PRS15	1	81L431
PRS15	1	81L851
PRS17	1	81L957
PRS19	1	81L097
PRS23	1	81L707
PRS40	1	81L421
SPN07	1	81L788
SPN09	1	81L533
SPN09	1	81L857
SPN10	1	81L432
SPN12	1	81L433

SPN14	1	81L981
SPN15	1	81L931
SPN23	1	81L778

08/22/82 EMPLOYEE GROUPING

WORK UNIT	LEVEL	EMPLOYEE
ASSEMBLY1	2	196966666
ASSEMBLY1	2	219005120
ASSEMBLY2	2	007824299
ASSEMBLY2	2	178697852
ASSEMBLY2	2	219674569
ASSEMBLY2	2	423997268
BLS03	1	126320076
BLS07	1	158288122
BLS11	1	192922376
BLS12	1	279026202
BLS15	1	782890108
BLS17	1	513330122
BLS23	1	321187237
BLS33	1	323033452
BLS37	1	630001256
BLS43	1	666902354
CNT05	1	736774236
CNT12	1	198882525
FABRICATN	3	107290088
FINISHING	2	456782156
MC09	1	218190233
MC15	1	256364253

MC16	1	162062612
MC18	1	525267654
MC21	1	762340088
MC23	1	336245123
MC29	1	509091767
MC45	1	156621111
MISNOUS	2	327500001
PLANT	4	011294234
PLANT	4	178215623
PLANT	4	346562819
POLE06	1	555197767
POLE15	1	019297862
PRODUCT	3	167254312
PRODUCT	3	269395214
PRS09	1	156723308
PRS14	1	009231567
PRS15	1	427293614
PRS17	1	542437329
PRS19	1	176320188
PRS23	1	209247230
PRS40	1	219045262
SERVICE	3	012035568
SERVICE	3	012928624
SERVICE	3	123392182
SERVICE	3	206090184
SERVICE	3	246420188
SERVICE	3	313190299
SERVICE	3	314900191
SERVICE	3	333290160
SERVICE	3	349270999
SERVICE	3	453563236
SERVICE	3	732568818

SPN07	1	039374153
SPN09	1	737012854
SPN10	1	467263234
SPN12	1	513397467
SPN15	1	444142468
SPN23	1	382522536

08/22/82 EQUIPMENT GROUPING

WORK UNIT	LEVEL	EQUIPMENT
ASSEMBLY1	2	TK05
BALLAST	2	BG05
CENTRAL	2	BG01
CENTRAL	2	MT12
CENTRAL	2	MT25
FABRICATN	3	MK15
FINISHING	2	WH01
MACHINE	2	MT09
PLANT	4	CM09
PLANT	4	WH03
POLE	2	TK19
PRESS	2	PB07
PRODUCT	3	BL30
SERVICE	3	MT41
SERVICE	3	TK01
SPINNING	2	MK03

08/22/82 WORK-UNIT GROUPING

WORK UNIT	LEVEL	SUBORDINATE WORK UNIT
BALLAST	2	BLS03
BALLAST	2	BLS07
BALLAST	2	BLS11
BALLAST	2	BLS12
BALLAST	2	BLS15
BALLAST	2	BLS17
BALLAST	2	BLS19
BALLAST	2	BLS23
BALLAST	2	BLS33
BALLAST	2	BLS37
BALLAST	2	BLS43
CENTRAL	2	CNT05
CENTRAL	2	CNT12
FABRICATN	3	BALLAST
FABRICATN	3	FINISHING
FABRICATN	3	MACHINE
FABRICATN	3	PRESS
FABRICATN	3	SPINNING
MACHINE	2	MC09
MACHINE	2	MC15
MACHINE	2	MC16
MACHINE	2	MC17
MACHINE	2	MC18
MACHINE	2	MC21
MACHINE	2	MC23
MACHINE	2	MC29
MACHINE	2	MC45

PLANT	4	FABRICATN
PLANT	4	PRODUCT
PLANT	4	SERVICE
POLE	2	POLE06
POLE	2	POLE15
PRESS	2	PRS09
PRESS	2	PRS12
PRESS	2	PRS14
PRESS	2	PRS15
PRESS	2	PRS17
PRESS	2	PRS19
PRESS	2	PRS23
PRESS	2	PRS40
PRODUCT	3	ASSEMBLY1
PRODUCT	3	ASSEMBLY2
PRODUCT	3	CENTRAL
PRODUCT	3	MISNCUS
PRODUCT	3	POLE
SPINNING	2	SPN07
SPINNING	2	SPN09
SPINNING	2	SPN10
SPINNING	2	SPN12
SPINNING	2	SPN14
SPINNING	2	SPN15
SPINNING	2	SPN23

08/22/82 OVERHEAD OF WORK UNIT

WORK UNIT	LEVEL	OVERHEAD($)

ASSEMBLY1	2	288.60
ASSEMBLY2	2	473.31
BALLAST	2	40.26
BLS03	1	162.43
BLS07	1	110.10
BLS11	1	83.33
BLS12	1	288.80
BLS15	1	391.68
BLS17	1	118.82
BLS19	1	36.42
BLS23	1	246.03
BLS33	1	110.40
BLS37	1	157.22
BLS43	1	158.89
CENTRAL	2	73.43
CNT05	1	65.72
CNT12	1	113.64
FABRICATN	3	151.93
FINISHING	2	192.23
MACHINE	2	3.50
MC09	1	200.44
MC15	1	84.09
MC16	1	160.00
MC17	1	35.90
MC18	1	238.81
MC21	1	207.20
MC23	1	146.41
MC29	1	179.60
MC45	1	370.20
MISNOUS	2	181.27
PLANT	4	1,037.78
POLE	2	134.52

POLE06	1	99.16
POLE15	1	130.40
PRESS	2	7.80
PRODUCT	3	249.18
PRS09	1	252.00
PRS12	1	424.64
PRS14	1	307.14
PRS15	1	231.63
PRS17	1	119.69
PRS19	1	99.20
PRS23	1	153.39
PRS40	1	80.70
SERVICE	3	1,094.75
SPINNING	2	106.69
SPN07	1	$136.59
SPN09	1	171.87
SPN10	1	93.00
SPN12	1	107.04
SPN14	1	50.01
SPN15	1	111.22
SPN23	1	108.02

P/* INV DATA (INPUT DATA OF INVENTORY FILE)

08/22/82 INVENTORY FILE

ITEM NO	UNIT OF MEASURE	BASE COST($)	CURRENT COST($)	OPERATION TIME(MIN)
NRG121	EA	212.35	280.07	304.19
PVLXXXXXXXX	EA	66.25	82.25	141.07
PVL0175H118	EA	183.13	214.92	220.57

QL505	EA	69.53	87.33	86.85
13310340024	LB	.18	.30	.00
13310600048	LB	.62	.80	.00
13311210309	LB	.25	.31	.00
13311300845	EA	1.21	1.53	.00
13314900022	LB	1.01	1.21	.00
13314900030	LB	1.12	1.56	.00
13355000592	LB	.05	.06	.00
13357400542	LB	.81	.99	.00
14210530180	LB	1.20	1.36	.00
14255110267	LB	6.35	6.45	.00
14455700115	LB	.36	.70	.00
20001170107	EA	6.35	7.82	2.64
20001179901	EA	6.20	7.13	.00
20001220118	EA	4.19	5.32	5.18
20001229904	EA	3.19	4.29	.00
20001239903	EA	3.19	4.29	.00
20001329803	EA	9.33	10.33	.00
20001329902	EA	9.33	10.33	.00
20101470118	EA	4.21	5.84	3.77
20101479904	EA	4.01	5.06	.00
20750110107	EA	5.12	6.02	.00
21000579902	EA	2.45	4.13	.00
22103930108	EA	1.11	1.46	3.26
22103940107	EA	.21	.41	1.92
22602600103	EA	.58	.71	3.52
22700010113	EA	33.12	43.62	8.17
22707870106	EA	.15	.20	.63
22708360114	EA	21.20	26.25	13.64
22901130124	EA	.51	.79	.73
22901140123	EA	.71	.97	1.24
22901280101	EA	.49	.60	.75

22901300107	EA	.40	.47	.49
23100790115	EA	20.01	22.53	2.25
23100809908	EA	.35	.51	.00
23103279900	EA	1.21	1.50	.00
23111469907	EA	.09	.12	.00
23111689901	EA	.09	.12	.00
23112259901	EA	.13	.20	.00
23112329902	EA	.12	.41	.00
23112449908	EA	.06	.11	.00
23112459907	EA	.15	.30	.00
23112529908	EA	.08	.11	.00
23113139904	EA	.19	.26	.00
23113249901	EA	.05	.05	.00
23113299906	EA	.05	.05	.00
23113519908	EA	.15	.15	.00
23800269907	EA	1.00	1.63	.00
25400019906	EA	.50	.60	.00
25400209903	EA	.12	.15	.00
25402609903	EA	.25	.40	.00
25403349904	EA	1.28	1.97	.00
25403469900	EA	3.12	3.98	.00
25500149900	EA	2.11	3.22	.00
26000969905	EA	3.19	5.21	.00
26000979904	EA	1.20	1.25	.00
26001019907	EA	3.10	4.21	.00
26103429905	EA	12.25	13.64	.00
26261410333	EA	.55	.68	.92
26261411555	EA	2.73	3.21	7.00
26261411852	EA	.35	.67	.81
26261419905	FT	.13	.15	.00
26261420936	EA	.18	.33	.42
26261421265	EA	.95	1.03	.42

26261421851	EA	2.32	3.24	10.37
26261429904	FT	.25	.31	.00
26261439903	FT	.19	.19	.00
26310819907	EA	35.16	51.26	.00
26401849904	EA	12.91	15.88	.00
26504759901	EA	.77	1.02	.00
26504799907	EA	.81	1.23	.00
26504819903	FT	.75	.99	.00
26505209806	FT	.88	1.23	.00
26505329901	EA	.76	.98	.00
26505549905	EA	8.45	9.34	.00
26550599905	EA	.43	.59	.00
26600509903	EA	12.35	15.30	.00
26707279904	EA	1.02	1.21	.00
26708169906	EA	.19	.31	.00
26708229908	EA	3.00	3.26	.00
26708309908	EA	2.09	2.03	.00
26802659902	EA	.89	1.21	.00
26803069902	EA	.25	.29	.00
26803319901	EA	1.11	1.56	.00
26900889906	EA	.20	.23	.00
26905999908	EA	.08	.12	.00
26906219909	EA	.08	.11	.00
26906229908	EA	.10	.15	.00
26906329906	EA	.04	.06	.00
26906339905	EA	.05	.08	.00
26906429904	EA	.05	.06	.00
26906599905	EA	.05	.06	.00
26906989908	EA	.10	.12	.00
26907019902	EA	.05	.08	.00
26907020107	EA	1.86	2.33	6.20
26907089905	EA	.03	.04	.00

27100019905	EA	.05	.06	.00
27100809900	EA	.23	.30	.00
27101049901	EA	.39	.39	.00
27101099906	EA	.12	.25	.00
27800059904	FT	.20	.29	.00
27800609907	EA	.34	.49	.00
27800809903	EA	.55	.56	.00
60001200504	EA	.70	.94	2.41
60030511112	EA	46.25	59.77	72.38
60070000406	EA	20.95	26.89	39.37
60070000703	EA	2.25	3.11	3.76
60104019901	LB	3.20	3.99	.00
60200209901	LB	.25	.41	.00
60300129900	EA	.63	.80	.00
60301001206	EA	.23	.41	.00
60302000108	EA	8.12	11.21	.00
60303119908	EA	5.10	6.39	.00
60305019908	FT	.43	.62	.00
60306109905	EA	1.21	1.35	.00
60306119905	FT	.81	.96	.00
60400000109	EA	.60	.60	1.89
60400000505	EA	.90	.85	2.34
60400019902	EA	1.21	1.52	.00
60500029900	LB	.63	.88	.00
60600039908	EA	.88	1.21	.00
60710319901	EA	.13	.23	.00
60800109907	EA	9.21	12.31	.00
60800110102	EA	1.25	1.98	1.44
60800119906	EA	1.05	1.52	.00
60800129905	EA	2.12	2.00	.00
60800140109	EA	.81	.63	.49
60800149903	EA	.43	.46	.00

60800160107	EA	.45	.46	1.19
60800169901	EA	.12	.13	.00
60801050109	EA	.40	.49	1.26
60801059903	EA	.08	.09	.00
76607050813	EA	.08	.11	.00
76623051019	EA	.09	.11	.00
76623190411	EA	.08	.09	.00
76623451615	EA	.06	.09	.00
77695260117	EA	.06	.06	.00
77790080105	EA	.06	.06	.00
78969042405	EA	.04	.05	.00
79684040211	EA	.03	.04	.00
80011670406	EA	6.44	7.42	14.37
80011770214	EA	6.74	8.73	29.59
80011920108	EA	10.12	12.48	41.08
80019560104	EA	22.10	27.24	8.98
80020680107	EA	22.19	24.96	10.73
80020730100	EA	4.93	6.27	9.29
911XXXXXXX	EA	8.20	9.21	.00

P/* MC DATA (INPUT DATA OF MACHINE FILE)
08/22/82 MACHINE FILE

MACHINE NO	YEARLY VALUE($)	ENERGY CODE	HOURLY CONSUMPTION	WEIGHT INDEX
71X773	$4,600	ELEC	8.27	50.0
74A532	15,600	ELEC	4.56	1.0
75X457	2,500	HYDG	1.25	15.0
77L231	4,690	ELEC	1.95	15.0
77L321	5,500	ELEC	2.14	75.0

77M511	22,200	ELEC	9.23	25.0
77X256	3,330	ELEC	.88	50.0
77X323	1,900	OXYG	2.32	25.0
81L097	4,500	ELEC	1.59	25.0
81L419	8,000	ELEC	3.54	5.0
81L421	990	PETA	2.67	15.0
81L423	8,900	ELEC	2.94	75.0
81L427	11,200	ELEC	3.13	100.0
81L431	12,600	ELEC	1.58	30.0
81L432	4,250	ELEC	1.88	15.0
81L433	9,000	ELEC	.95	15.0
81L437	8,500	ELEC	1.22	15.0
81L500	9,100	ELEC	5.12	75.0
81L526	8,100	ELEC	5.45	10.0
81L527	7,500	ELEC	2.11	30.0
81L531	8,500	ELEC	1.05	10.0
81L533	9,500	PETB	2.67	25.0
81L536	8,800	HYDG	2.34	50.0
81L559	10,500	ELEC	7.31	50.0
81L633	25,500	ELEC	10.25	50.0
81L635	6,050	ELEC	5.69	50.0
81L691	12,500	ELEC	1.21	75.0
81L693	9,000	ELEC	2.36	75.0
81L707	15,200	GAS	3.24	75.0
81L713	8,800	ELEC	4.44	50.0
81L727	15,300	PETA	3.62	50.0
81L732	9,800	ELEC	5.24	75.0
81L778	6,000	ELEC	6.34	35.0
81L783	5,900	ELEC	8.89	25.0
81L788	12,900	ELEC	7.76	5.0
81L833	8,000	ELEC	12.00	25.0
81L844	1,800	ELEC	15.26	65.0

81L851	900	ELEC	5.23	35.0
81L855	5,900	ELEC	3.53	100.0
81L857	6,300	ELEC	8.16	100.0
81L883	100,000	PETA	4.25	25.0
81L923	32,500	ELEC	1.89	15.0
81L931	8,800	ELEC	5.12	25.0
81L933	4,230	ELEC	3.53	50.0
81L957	9,200	ELEC	4.86	30.0
81L981	12,500	ELEC	4.39	10.0
81L983	81,200	ELEC	1.56	25.0
81L987	4,200	ELEC	.89	25.0
81L991	52,300	ELEC	1.25	100.0
81L993	32,600	ELEC	2.60	25.0
81L995	31,500	OXYG	2.16	50.0
81L997	58,900	ELEC	2.56	75.0

P/* OP DATA (INPUT DATA OF OPERATION FILE)

08/22/82 OPERATION FILE (TIME MEASURED IN MIN)

OPERATION NO	TOOL CODE	STANDARD TIME	MINIMUM TIME	LABOR TIME	LABOR SKILL	MACHINE TIME	MACHINE NO
118000	T3235	9.81	8.38	6.58	PRS3	7.67	81L713
118001	T4566	2.23	2.23	2.11	BLS1	1.56	81L713
118002	T6628	1.92	1.80	1.83	BLS3	1.55	81L727
118003	T4566	6.13	5.80	5.37	BLS1	4.96	81L732
118004	T2342	1.62	1.22	1.39	BLS3	1.55	81L991
118005	T7549	.77	.77	.75	BLS1	.72	81L933
118006	T7581	2.43	2.45	2.40	PRS3	2.39	81L883
118007	T7549	.42	.40	.32	PRS3	.26	81L851
118008	T4355	1.18	1.05	.56	PRS1	1.09	81L855

118009	T3235	1.83	1.50	1.39	PRS1	1.35	81L683
118010	T7623	3.64	3.50	3.60	PRS1	3.57	81L997
118011	T3235	.92	.60	.76	DRI1	.88	81L857
118013	T2342	3.26	3.20	2.25	DRI1	3.07	81L991
118133	T1773	3.26	3.20	2.96	DRI3	3.08	77L321
118144	T2347	5.67	5.60	7.19	DRI1	7.13	81L933
118200	T4566	3.80	3.80	2.75	DRI1	3.37	71X773
118221	T7777	1.49	1.50	.89	THP1	.32	81L855
118227	T3235	1.71	1.50	1.52	DRI1	.73	81L713
118229		1.20	.90	.91	THP1	.89	81L855
118231	T7623	6.26	6.00	6.23	MHI3	6.11	81L633
118254	T3235	4.33	4.30	3.95	DRI3	3.96	81L691
118255	T2347	.89	.80	.75	DRI1	.78	81L995
118260	T7549	1.82	1.70	1.77	REC1	1.56	75X457
118262	T4321	.49	.50	.37	BLS3	.43	71X773
118263	T2222	1.23	1.20	1.00	CRF3	1.22	81L691
118265	T7851	1.29	1.20	1.20	CRF3	1.09	71X773
118267	T6267	6.13	6.00	2.25	ASS1	5.00	71X773
118268	T7623	.44	.40	.32	BLS1	.39	71X773
118269	T8339	10.40	7.60	9.19	MCF3	8.23	81L995
118271	T9233	.29	.20	.27	DRI5	.13	81L855
118278	T3981	3.10	2.90	2.76	DRI3	3.10	81L855
118766	T7623	2.90	2.80	2.65	DRI1	2.89	71X773
118800	T4355	1.88	1.50	1.88	PUN3	1.78	81L727
118911	T3981	2.50	2.50	1.98	PRS3	2.32	81L933
119133	T3233	1.92	1.80	1.92	PUN1	1.90	77L231
119200	T4566	.49	.40	.40	PUN3	.42	81L633
119221	T6267	1.26	1.20	1.26	PRS3	1.22	81L855
119227	T2342	.92	.70	.81	PUN1	.38	81L783
119229	T4321	10.13	8.00	9.01	MCF1	8.55	81L633
119231	T3981	1.18	1.15	1.11	CRF1	1.02	81L993
119254	T2563	6.77	5.80	6.70	BLS1	5.75	71X773

119262		.92	.90	.90	CRF1	.88	71X773
119265	T7623	3.56	3.30	3.33	THP1	3.21	71X773
119267	T3981	1.92	1.80	1.89	ASS1	1.56	71X773
119269	T7777	3.00	2.80	3.00	PRS1	2.77	81L993
119766	T4566	5.63	5.50	5.43	PRS1	5.55	71X773
119800	T4355	1.37	1.30	1.32	PRS1	1.23	71X773
120133	T3981	.75	.56	.52	BLS1	.70	81L991
120200	T4261	5.18	5.10	4.99	BLS1	4.86	77L231
120231	T7923	2.36	2.30	1.99	BLS1	2.12	81L993
120254	T6628	7.37	6.30	6.36	MCF1	6.21	81L421
120262		.81	.80	.81	PUN1	.81	81L533
120265	T2342	2.36	1.80	2.06	REC1	2.21	81L421
120269		3.78	2.75	3.55	BLS1	3.78	81L993
120766	T9383	3.56	3.50	3.33	ASS1	3.12	81L707
120800	T2222	3.26	3.00	3.25	BLS1	3.02	81L633
121133	T1773	.49	.30	.30	PUN1	.44	81L983
121137	T7623	.43	.42	.43	CRF3	.00	
121142	T1773	11.88	11.88	11.88	PRS1	11.52	81L983
121167	T2342	1.08	.95	.96	DRI1	1.02	81L991
121175	T2342	.54	.50	.52	DRI1	.43	81L993
121177	T2342	.83	.80	.82	DRI1	.80	81L991
121183	T7549	9.67	9.60	9.67	DRI1	9.66	81L991
121191	T7549	4.87	3.50	4.87	DRI3	4.82	81L991
121195	T7549	.77	.77	.77	DRI1	.72	81L933
121197	T2342	1.26	1.20	1.25	DRI1	1.20	81L991
121200	T7623	1.64	1.50	1.62	DRI1	1.63	81L997
121203	T3233	1.03	1.00	1.00	DRI3	.83	81L987
121205	T3235	1.83	1.50	1.79	DRI1	1.25	81L531
121206	T7851	3.43	3.45	3.42	PUN1	2.38	81L883
121207	T3235	.92	.60	.91	PUN1	.92	81L857
121208	T4355	1.18	1.05	1.05	DRI1	1.18	81L855
121209	T7549	.42	.40	.25	BLS1	.40	81L851

121210	T2342	5.62	4.62	5.50	BLS1	5.25	81L559
121215	T7623	1.12	1.08	1.12	BLS1	.88	81L851
121217	T6267	1.44	1.43	1.44	BLS3	1.33	81L844
121227	T4566	3.13	2.80	2.98	BLS1	3.00	81L531
121228	T7851	3.73	3.40	3.71	PUN1	3.56	81L707
121229	T9233	8.16	7.10	6.12	BLS3	7.02	81L783
121230	T9233	40.27	38.25	39.00	BLS1	38.12	81L983
121231	T6628	4.92	4.80	4.88	PRS1	4.88	81L559
121232	T4566	2.23	2.23	1.97	PRS1	2.23	81L713
121233	T4261	.50	.40	.47	PRS3	.42	81L427
121234	T3235	2.31	2.10	1.95	PRS1	1.81	81L693
121235	T3981	.99	.80	.93	PRS1	.89	81L691
121237	T3981	4.25	4.22	4.20	PRS1	4.21	81L635
121239	T2563	5.33	5.30	5.30	PUN1	4.62	81L633
121250	T1773	1.89	2.00	1.80	DRI5	1.85	81L981
121254	T2347	8.29	8.00	8.25	DRI3	7.33	81L783
121256	T7549	1.82	1.50	1.78	PUN1	1.69	81L788
121260	T2222	11.17	10.15	11.05	PUN3	12.05	81L997
121261	T4566	4.23	4.30	3.96	PUN1	3.25	81L997
121262	T7777	10.37	11.35	12.37	DRI1	11.78	81L435
121263	T3235	1.73	1.60	1.73	DRI3	1.55	81L693
121264	T8339	2.05	1.90	2.00	DRI1	1.88	81L531
121265	T4355	18.12	18.12	17.98	BLS1	18.12	81L559
121266	T9393	1.01	.60	.78	ASS1	1.00	81L559
121267	T6267	21.78	18.75	19.43	BLS1	17.56	77M511
121268	T9383	.90	.90	.88	ASS1	.56	77M511
121269	T4566	.97	.85	.43	PUN3	.76	81L437
121270	T4321	6.23	6.20	6.20	PUN3	6.15	81L431
121271	T7623	5.69	5.65	4.67	PUN1	5.56	81L531
121272	T6267	.93	.90	.93	PUN1	.90	81L931
121275	T3981	3.16	3.16	3.16	PRS1	3.00	81L419
121278	T7623	.88	.87	.79	PRS1	.52	77M511

121290	T4261	3.03	2.80	2.98	PRS3	2.22	81L957
121295	T3981	.92	.90	.89	PRS1	.79	81L995
121600	T4261	2.39	2.30	1.99	BLS1	1.26	77M511
121601	T7623	.89	.85	.64	BLS3	.80	81L778
121602	T2563	1.18	1.15	1.13	BLS1	1.12	81L431
121603	T4566	1.23	1.20	1.20	CRF1	1.02	81L851
121604	T2222	5.36	4.33	5.33	MHI5	5.00	81L433
121605	T4261	.27	.30	.27	PUN3	.27	81L987
121606	T7549	1.26	1.20	1.25	PUN1	1.00	81L693
121607	T9233	1.23	1.21	1.23	PUN1	1.00	81L693
121608		10.01	9.00	7.93	ASS1	8.56	81L957
121610	T6628	3.13	2.00	3.13	THP3	2.33	74A532
121766		.80	.80	.53	ASS1	.77	81L783
121796	T7851	3.29	3.30	2.76	PUN1	3.29	77M511
121800	T7777	6.23	6.20	4.32	PUN1	6.00	81L559
121813	T7623	1.26	1.20	1.22	PUN1	1.20	81L423
122133	T7549	.63	.60	.60	PUN3	.62	81L732
122231	T7623	.92	.80	.92	BLS1	.88	81L633
122262	T4566	7.00	6.70	6.89	BLS3	5.82	81L707
122265	T4566	1.40	1.20	1.23	CRF3	1.25	77X323
122269	T7623	1.89	1.85	1.23	BLS3	1.25	81L437
122270	T7777	.78	.78	.78	ASS3	.78	77M511
122271	T6267	.76	.80	.76	CRF1	.52	75X457
122278	T9233	25.42	24.45	24.25	PRS1	22.40	77M511
122600	T6267	2.99	2.95	2.78	PRS1	1.97	77M511
122603	T4321	5.42	4.45	4.02	MCF5	3.41	81L778
122604	T6267	1.89	1.60	1.79	MCF3	1.23	81L419
122608		1.23	1.20	1.09	ASS1	1.23	81L957
122911	T7623	1.76	1.75	1.58	DRI5	1.76	81L983
122913	T9233	.91	.50	.91	BLS3	.45	81L693
123231	T7549	.97	.86	.78	PUN1	.76	81L531
123262	T7777	20.88	20.85	19.80	PUN3	9.12	81L432

123265	T9393	.88	.88	.65	ASS1	.88	
123269	T3981	6.71	6.70	6.13	PRS3	6.25	81L437
123271	T6267	.49	.50	.46	ASS3	.48	77M511
123600	T9233	2.21	2.22	1.38	PUN3	2.21	81L533
123603	T2347	4.23	4.20	3.99	THP3	3.79	81L432
123604	T7623	.92	.50	.88	CRF1	.42	81L433
123608	T9383	1.23	1.20	1.23	ASS1	1.20	81L097
124231	T3981	2.92	1.98	2.72	ASS3	2.92	81L923
124262	T2563	.42	.45	.39	REC1	.38	81L778
124263	T6267	1.92	1.70	1.88	PRS1	1.33	81L783
124269		5.26	5.20	5.00	PRS3	5.20	81L778
124272	T9233	2.40	2.00	2.40	PUN1	2.02	81L981
124600	T7851	.89	.80	.76	PUN3	.80	81L693
124603	T8339	2.40	2.40	2.40	ASS3	2.20	81L431
124604	T3981	2.34	2.31	2.25	DRI3	1.88	81L707
124608	T2342	.99	1.00	.98	THP3	.32	81L097
125231	T6267	1.45	1.20	1.35	THP1	1.22	75X457
125262	T7623	1.88	1.50	1.39	PRS1	1.25	81L419
125269	T7623	6.20	6.20	6.20	PRS3	6.02	81L423
125272	T7549	.92	.80	.76	ASS3	.68	77M511
125603	T7851	1.28	1.20	1.19	THP3	1.12	81L851
125608	T7549	.49	.30	.45	ASS1	.35	81L957
126231		.80	.80	.76	CRF1	.39	81L923
126262	T7851	.92	.80	.89	ASS3	.69	81L533
126269	T7623	2.92	2.90	2.90	CRF3	2.35	81L931
126603	T1773	1.75	1.70	1.72	BLS1	1.25	81L423
126608	T7549	1.63	1.50	1.54	BLS1	1.63	81L419
127269	T4321	3.81	3.80	2.79	REC3	3.76	81L931
127603	T7623	1.09	1.00	1.08	DRI5	1.02	81L857
127608	T2342	1.44	1.00	1.42	DRI3	1.00	81L419
128269	T7623	12.17	12.20	12.09	CRF3	12.07	81L533
128603	T7623	2.13	2.00	2.11	PUN3	2.03	81L693

128608	T6628	.49	.44	.49	PUN3	.46	81L788
129269	T4355	2.10	2.02	2.02	CRF1	2.02	81L433
129608	T9383	1.19	1.20	.92	ASS1	1.12	81L788
130269	T9393	8.12	6.90	8.02	ASS1	8.01	81L693
130608	T4355	1.26	.53	1.26	ASS3	1.25	81L419
131269	T7549	3.10	2.32	3.10	PUN1	3.10	81L987
505133	T4355	.73	.70	.71	BLS1	.70	81L983
505142	T3235	3.52	3.50	2.78	BLS1	2.85	77L231
505200	T7623	3.33	3.00	1.98	DRI1	3.02	81L527
505201	T2342	3.22	3.70	3.20	DRI1	3.20	81L783
505202	T3981	1.83	1.80	1.80	DRI3	1.27	81L883
505204	T6267	3.47	3.30	2.40	DRI1	2.25	81L526
505205	T2342	3.49	3.50	3.47	DRI1	3.47	81L713
505207	T8339	1.83	1.50	1.35	CRF3	1.62	81L527
505226	T9393	.77	.70	.72	ASS1	.56	81L526
505229	T3981	1.88	1.20	1.63	PUN3	1.56	81L527
505230	T5215	2.43	2.40	2.37	PUN1	2.42	81L844
505231	T9393	.45	.45	.43	ASS1	.40	81L844
505238	T7549	2.37	2.30	2.09	BLS3	2.35	81L833
505239	T9383	1.05	.90	1.03	ASS1	1.00	
505254	T7623	8.21	8.00	8.02	BLS1	8.01	81L527
505255		1.00	1.00	.79	ASS1	.56	
505260	T9233	3.76	3.50	3.56	BLS3	3.35	81L526
505261	T7549	.92	.85	.79	DRI5	.82	81L437
505262		.63	.50	.63	ASS1	.63	77X323
505263	T1773	1.99	1.50	1.87	DRI3	1.56	81L788
505264	T4355	1.82	1.50	1.79	ASS3	1.52	71X773
505265		.92	.80	.92	DRI1	.88	74A532
505267	T2222	1.88	1.88	1.78	THP3	1.56	74A532
505268	T2563	4.78	3.80	4.65	BLS1	4.63	74A532
505271	T4566	1.13	1.00	1.09	BLS3	1.05	77X256
505278	T3981	2.27	2.30	2.12	BLS1	2.02	77X323

505300	T7623	1.38	1.20	1.18	THP1	1.27	74A532
505350	T4321	3.41	2.00	3.25	ASS3	3.40	77M511
505400	T8339	.77	.60	.77	CRF3	.00	
505450	T7851	1.19	1.00	1.18	PUN3	.00	
505766	T7777	1.45	1.40	1.42	BLS1	1.40	77X323
505776	T4566	3.97	3.60	2.98	PRS1	2.56	77X256
505777	T2347	3.76	3.50	3.70	DRI1	3.33	77X256
505789	T2347	1.65	1.60	1.65	DRI3	1.35	81L427
505800	T9233	1.33	1.20	1.25	PUN1	1.02	81L981
506133	T6628	1.24	1.20	1.20	PUN1	1.24	81L991
506200	T8339	2.64	2.60	2.52	BLS1	2.63	81L427
506201	T6628	3.77	3.70	3.25	BLS1	2.76	77L321
506229	T4321	10.88	10.50	10.16	REC3	10.82	81L427
506231	T2222	3.31	3.00	3.12	THP3	3.25	81L833
506265	T3981	1.82	1.82	1.78	ASS3	1.56	74A532
506271	T3981	3.51	3.50	3.29	CRF1	3.22	77X256
507231	T7623	1.92	1.60	1.89	DRI3	1.88	75X457
507265	T3981	1.42	1.38	1.36	THP3	1.42	74A532

P/* PS DATA (SAMPLE INPUT DATA OF PRODUCT STRUCTURE)

08/22/82 PRODUCT STRUCTURE FILE

PARENT PRODUCT	CHILD PRODUCT	QUANTITY USED	OPERA-TION NO	WORK UNIT
NRG121	20001329803	1.000	121200	MC45
NRG121	20001329902	1.000	121205	MC45
NRG121	21000579902	1.000	121210	MC45
NRG121	22708360114	1.000	121227	MC45
NRG121	23113249901	4.000	121231	MC45
NRG121	23113299906	1.000	122231	MC45
NRG121	23113519908	1.000	123231	MC45

NRG121	25400019906	3.000	121254	BLS03
NRG121	26001019907	1.000	121260	MC45
NRG121	26103429905	1.000	121261	MC45
NRG121	26261411555	1.000	121262	SPN12
NRG121	26505549905	1.000	121265	MC45
NRG121	26600509903	1.000	121266	MC45
NRG121	26708229908	1.000	121267	ASSEMBLY1
NRG121	26803319901	1.000	121268	ASSEMBLY1
NRG121	26900889906	1.000	121269	MC16
NRG121	26906229908	1.000	122269	MC16
NRG121	26906339905	1.000	123269	MC16
NRG121	26907019902	1.000	124269	SPN23
NRG121	26907089905	1.000	125269	PRS15
NRG121	27100019905	.001	121271	MC45
NRG121	27800059904	.300	121278	ASSEMBLY1
NRG121	27800809903	.001	122278	ASSEMBLY1
NRG121	60030511112	1.000	121600	ASSEMBLY1
NRG121	60070000406	1.000	122600	ASSEMBLY1
NRG121	79684040211	1.000	121796	ASSEMBLY1
NRG121	80019560104	1.000	121800	MC45
PVLXXXXXXXX	20001220118	1.000	118200	ASSEMBLY2
PVLXXXXXXXX	20001239903	1.000	119200	MC09
PVLXXXXXXXX	22103930108	1.000	118221	MC15
PVLXXXXXXXX	22103940107	1.000	119221	MC15
PVLXXXXXXXX	22901280101	1.000	118229	MC15
PVLXXXXXXXX	22901300107	2.000	119229	MC09
PVLXXXXXXXX	23103279900	2.000	118231	MC09
PVLXXXXXXXX	23111469907	14.000	119231	MC18
PVLXXXXXXXX	23111689901	2.000	120231	MC18
PVLXXXXXXXX	23112259901	4.000	121231	MC45
PVLXXXXXXXX	23112529908	2.000	122231	MC09
PVLXXXXXXXX	25403469900	1.000	119254	ASSEMBLY2

PVLXXXXXXX	26261411852	1.000	118262	ASSEMBLY2
PVLXXXXXXX	26261421851	1.000	119262	ASSEMBLY2
PVLXXXXXXX	26505209806	4.660	118265	ASSEMBLY2
PVLXXXXXXX	26505329901	1.000	119265	ASSEMBLY2
PVLXXXXXXX	26707279904	1.000	118267	ASSEMBLY2
PVLXXXXXXX	26708169906	4.000	119267	ASSEMBLY2
PVLXXXXXXX	26803069902	1.000	118268	ASSEMBLY2
PVLXXXXXXX	26900889906	1.000	119269	MC18
PVLXXXXXXX	26906229908	1.000	120269	MC18
PVLXXXXXXX	26906339905	1.000	121269	MC16
PVLXXXXXXX	26907019902	1.000	122269	MC16
PVLXXXXXXX	26907020107	1.000	123269	MC16
PVLXXXXXXX	27100019905	.001	118271	MC15
PVLXXXXXXX	27800609907	.001	118278	MC15
PVLXXXXXXX	76623190411	1.000	118766	ASSEMBLY2
PVLXXXXXXX	76623451615	4.000	119766	ASSEMBLY2
PVLXXXXXXX	80011670406	1.000	119800	ASSEMBLY2
PVLXXXXXXX	80020730100	1.000	120800	MC09
PVL0175H118	PVLXXXXXXX	1.000	118000	BLS23
PVL0175H118	22700010113	1.000	118227	BLS23
PVL0175H118	25400019906	7.000	118254	PRS14
PVL0175H118	25500149900	1.000	118255	PRS14
PVL0175H118	26310819907	1.000	118263	PRS14
PVL0175H118	26906329906	1.000	118269	PRS14
PVL0175H118	80011920108	1.000	118800	BLS23

P/* SK DATA (INPUT DATA OF LABOR SKILL)

08/22/82 LABOR SKILL FILE

SKILL CODE	BASE RATE($)	CURRENT RATE($)

ASS1	6.00	8.00
ASS3	12.00	14.00
BLS1	7.00	9.00
BLS3	15.00	18.00
CRF1	5.00	7.00
CRF3	10.00	13.00
DRI1	9.00	11.00
DRI3	12.00	14.00
DRI5	17.00	20.00
MCF1	8.00	10.00
MCF3	11.00	14.00
MCF5	17.00	20.00
MHI3	11.00	13.00
MHI5	18.00	21.00
PRS1	8.00	10.00
PRS3	13.00	16.00
PUN1	8.00	10.00
PUN3	10.00	13.00
REC1	7.00	10.00
REC3	12.00	14.00
S 2	15.00	17.00
THP1	6.00	8.00
THP3	8.00	10.00

P/* TL DATA (INPUT DATA OF TOOL FILE)

08/22/82 TOOL FILE

TOOL CODE	YEARLY COST($)	WEIGHT INDEX(%)

T1773	230	5.0
T2222	90	10.0
T2342	60	5.0
T2347	120	5.0
T2563	80	3.0
T3233	110	5.0
T3235	100	5.0
T3981	190	4.0
T4261	40	5.0
T4321	50	1.0
T4355	120	5.0
T4566	150	5.0
T5215	120	5.0
T6267	110	5.0
T6628	100	5.0
T7549	110	5.0
T7581	320	5.0
T7623	120	5.0
T7777	340	5.0
T7851	210	5.0
T7923	230	5.0
T8339	120	5.0
T9233	210	5.0
T9383	220	5.0

Appendix D. Data for Transaction Files

P/* JOB1 DATA (INPUT DATA OF SERVICES OUTPUT)
08/22/82 JOB1 FILE

WORK UNIT	JOB NO NO	JULIAN DATE	TIME IN H,M,S	HOUR	MIN	SEC	TIME OUT H,M,S	HOUR	MIN	SEC
BLS07	A3032	82070	09-25-31	9	25	31	09-55-12	9	55	12
CNT05	B3409	82070	08-00-00	8			09-12-10	9	12	10
CNT05	B3409	82070	11-11-00	11	11		12-00-00	12		
SPN09	C3090	82070	09-10-09	9	10	9	11-12-03	11	12	3
SPN09	C3090	82070	15-19-12	15	19	12	16-45-20	16	45	20

P/* JOB2 DATA (INPUT DATA OF NON-STANDARD PRODUCTS)
08/22/82 JOB2 FILE

WORK UNIT	JOB NO	ITEM OUTPUT	ITEM INPUT	QUANTITY FINISHED	JULIAN DATE
BLS07	A3032	QL505	60030511112	30.000	82240
CNT05	B3409	QL505	60030511112	40.000	82240
SPN09	C3045	26261411852	26906219909	240.000	82240
SPN09	C3090	26261410333	26906219909	320.000	82240

P/* JOB3 DATA (INPUT DATA OF STANDARD PRODUCTS)
08/22/82 JOB3 FILE

WORK UNIT	JOB NO	ITEM NO	QUANTITY COMPLETE	JULIAN	TIME
ASSEMBLY1	W1222	NRG121	11.000	82098	17.13.45

ASSEMBLY2	A1212	PVLXXXXXXXX	15.000	82098	17.13.45
BLS03	Q9001	80020730100	16.000	82098	17.13.45
BLS03	Q2343	NRG121	34.000	82098	17.13.45
BLS07	D5127	QL505	8.000	82098	17.13.45
BLS07	A5673	QL505	100.000	82098	17.13.45
BLS11	G3434	22700010113	120.000	82098	17.13.45
BLS12	C2312	22901140123	120.000	82098	17.13.45
BLS15	S2390	23100790115	111.000	82098	17.13.45
BLS15	S2389	22901130124	90.000	82098	17.13.45
BLS17	B1782	23100790115	120.000	82098	17.13.45
BLS23	C2312	PVL0175H118	112.000	82098	17.13.45
BLS33	C3412	QL505	200.000	82098	17.13.45
BLS37	A8967	QL505	145.000	82098	17.13.45
BLS43	A1212	QL505	169.000	82098	17.13.45
BLS43	C4646	QL505	43.000	82098	17.13.45
BLS43	R3223	QL505	37.000	82098	17.13.45
CNT05	S1211	QL505	189.000	82098	17.13.45
CNT12	A1121	QL505	189.000	82098	17.13.45
FINISHING	A9000	QL505	210.000	82098	17.13.45
MC09	A1211	PVLXXXXXXXX	120.000	82098	17.13.45
MC15	D0909	PVLXXXXXXXX	180.000	82098	17.13.45
MC16	A2090	PVLXXXXXXXX	180.000	82098	17.13.45
MC18	A2090	PVLXXXXXXXX	180.000	82098	17.13.45
MC18	B3409	PVLXXXXXXXX	45.000	82098	17.13.45
MC21	A9011	60030511112	165.000	82098	17.13.45
MC21	A9012	60070000406	120.000	82098	17.13.45
MC23	A2367	60070000406	149.000	82098	17.13.45
MC29	D1090	60070000406	129.000	82098	17.13.45
MC45	A3032	NRG121	8.000	82098	17.13.45
MC45	C3090	PVLXXXXXXXX	7.000	82098	17.13.45
MISNOUS	A8912	80020680107	178.000	82098	17.13.45
MISNOUS	S3298	80020730100	90.000	82098	17.13.45

POLE06	D0012	20001170107	120.000	82098	17.13.45
POLE06	D1211	20001220118	111.000	82098	17.13.45
POLE15	D0912	20101470118	120.000	82098	17.13.45
POLE15	D0913	22103930108	90.000	82098	17.13.45
PRS09	D8901	80019560104	125.000	82098	17.13.45
PRS09	S1290	80019560104	120.000	82098	17.13.45
PRS14	A2312	PVL0175H118	189.000	82098	17.13.45
PRS15	D1217	60001200504	120.000	82098	17.13.45
PRS15	D1218	26907020107	270.000	82098	17.13.45
PRS17	D2312	60070000406	200.000	82098	17.13.45
PRS19	D2309	60070000406	180.000	82098	17.13.45
PRS23	A9089	26261411555	190.000	82098	17.13.45
PRS40	B3434	80011670406	210.000	82098	17.13.45
PRS40	A2312	80020730100	110.000	82098	17.13.45
SPN07	A2111	60800140109	119.000	82098	17.13.45
SPN09	D6744	26261411852	120.000	82098	17.13.45
SPN09	D6745	26261410333	200.000	82098	17.13.45
SPN10	B7363	60030511112	80.000	82098	17.13.45
SPN10	A2309	80011770214	132.000	82098	17.13.45
SPN12	H3861	26261421851	90.000	82098	17.13.45
SPN15	C9087	60030511112	45.000	82098	17.13.45
SPN23	Q2323	60030511112	23.000	82098	17.13.45

P/* SCH DATA (INPUT DATA OF PRODUCTION SCHEDULE)

08/22/82 PRODUCTION SCHEDULE

ITEM NO	BACKLOG	1ST WK	2ND WK	3RD WK	4TH WK	5TH WK	6TH WK
NRG121	80.00	250.00	60.00	30.00	90.00	85.00	95.00
PVL0175H118	100.00	135.00	180.00	200.00	150.00	100.00	90.00
QL505	60.00	100.00	150.00	100.00	120.00	100.00	80.00

22708360114	.00	80.00	50.00	90.00	180.00	120.00	55.00
26261411555	80.00	120.00	90.00	40.00	20.00	120.00	77.00
26907089905	30.00	64.00	34.00	23.00	90.00	120.00	45.00
27800809903	50.00	90.00	120.00	77.00	112.00	88.00	39.00
60030511112	77.00	55.00	97.00	86.00	89.00	65.00	23.00
60070000406	23.00	120.00	.00	67.00	54.00	80.00	67.00
79684040211	33.00	33.00	33.00	44.00	22.00	33.00	44.00
80019560104	32.00	87.00	109.00	54.00	29.00	54.00	21.00
80020680107	34.00	109.00	123.00	109.00	112.00	111.00	23.00
80020730100	45.00	89.00	56.00	82.00	91.00	59.00	49.00

Appendix E. Output Listings

P/* ITEMCALL OUT (SAMPLE OUTPUT OF ITEM DIRECT COST)
08/22/82

ITEM NO	COST($)
NRG121	282.661
PVLXXXXXXXX	85.173
PVL0175H118	217.584
QL505	87.330
13310340024	.300
13310600048	.800
13311210309	.310
13311300845	1.530
13314900022	1.210
13314900030	1.560
13355000592	.060
13357400542	.990
14210530180	1.360
14255110267	6.450
14455700115	.700

P/* OPV OUT (OVERALL PARTIAL INPUT VALUE OF WORK UNITS)
08/22/82

WORKING UNIT	LABOR INPUT($)	CAPITAL INPUT($)	ENERGY INPUT($)
ASSEMBLY1	139.84	103.20	45.56
ASSEMBLY2	454.88	18.40	.03
BALLAST	970.64	928.92	4.82
BLS03	138.80	23.60	.03

BLS07	70.80	39.20	.10
BLS11	66.40	16.92	.01
BLS12	79.60	209.20	.00
BLS15	66.88	324.80	.00
BLS17	79.60	39.20	.02
BLS19	.00	36.40	.02
BLS23	149.28	96.40	.35
BLS33	80.40	30.00	.00
BLS37	124.80	32.40	.02
BLS43	114.08	44.80	.01
CENTRAL	158.08	83.64	11.07
CNT05	52.40	13.32	.00
CNT12	105.68	7.60	.36
FABRICATN	3,252.98	3,160.58	21.76
FINISHING	78.56	110.40	3.27
MACHINE	900.24	725.10	.81
MC09	98.40	102.00	.04
MC15	60.48	23.60	.01
MC16	126.00	34.00	.00
MC17	.00	35.20	.70
MC18	108.40	130.40	.01
MC21	171.20	36.00	.00
MC23	114.40	32.00	.01
MC29	162.80	16.80	.00
MC45	58.56	311.60	.04
MISNOUS	170.88	10.00	.39
PLANT	5,810.62	4,224.88	341.58
POLE	188.80	55.14	120.14
POLE06	80.40	18.76	.00
POLE15	108.40	22.00	.00
PRESS	727.76	945.36	3.07
PRODUCT	1,253.42	370.38	185.43

PRS09	122.00	130.00	.00
PRS12	.00	424.20	.44
PRS14	130.80	176.00	.34
PRS15	142.00	89.60	.03
PRS17	82.88	36.80	.01
PRS19	81.20	18.00	.00
PRS23	92.40	60.80	.19
PRS40	76.48	3.96	.26
SERVICE	978.50	17.92	98.33
SPINNING	500.40	378.20	5.84
SPN07	84.96	51.60	.03
SPN09	108.40	63.20	.27
SPN10	76.00	17.00	.00
SPN12	71.04	36.00	.00
SPN14	.00	50.00	.01
SPN15	76.00	35.20	.02
SPN23	84.00	24.00	.02

P/* OTV OUT (OVERALL TOTAL INPUT VALUE OF WORK UNITS)
08/22/82

WORK UNIT	TOTAL INPUT($)
ASSEMBLY1	288.60
ASSEMBLY2	473.31
BALLAST	1,904.38
BLS03	162.43
BLS07	110.10
BLS11	83.33
BLS12	288.80

BLS15	391.68
BLS17	118.82
BLS19	36.42
BLS23	246.03
BLS33	110.40
BLS37	157.22
BLS43	158.89
CENTRAL	252.79
CNT05	65.72
CNT12	113.64
FABRICATN	6,435.32
FINISHING	192.23
MACHINE	1,626.15
MC09	200.44
MC15	84.09
MC16	160.00
MC17	35.90
MC18	238.81
MC21	207.20
MC23	146.41
MC29	179.60
MC45	370.20
MISNOUS	181.27
PLANT	10,377.08
POLE	364.08
POLE06	99.16
POLE15	130.40
PRESS	1,676.19
PRODUCT	1,809.23
PRS09	252.00
PRS12	424.64
PRS14	307.14

PRS15	231.63
PRS17	119.69
PRS19	99.20
PRS23	153.39
PRS40	80.70
SERVICE	1,094.75
SPINNING	884.44
SPN07	136.59
SPN09	171.87
SPN10	93.00
SPN12	107.04
SPN14	50.01
SPN15	111.22
SPN23	108.02

P/* PPTYTALL OUT (PARTIAL PRODUCTIVITY MEASURED IN MINUTE/DOLLAR)
LBPR: LABOR PRODUCTIVITY
CAPR: CAPITAL PRODUCTIVITY
ENPR: ENERGY PRODUCTIVITY

08/22/82 PARTIAL PRODUCTIVITY MEASURES

WORK UNIT	TIME ADDED (MIN)	LABOR ($)	LBPR	CAPITAL ($)	CAPR	ENERGY ($)	ENPR
ASSEMBLY1	634.15	139.84	4.53	103.20	6.14	45.56	13.91
ASSEMBLY2	528.30	454.88	1.16	18.40	28.71	.03	17,610.00
BLS03	296.58	138.80	2.13	23.60	12.56	.03	9,886.00
BLS07	662.04	70.80	9.35	39.20	16.88	.10	6,620.40
BLS11	490.20	66.40	7.38	16.92	28.97	.01	49,020.00
BLS12	74.40	79.60	.93	209.20	.35	.00	*
BLS15	522.12	66.88	7.80	324.80	1.60	.00	*

BLS17	117.60	79.60	1.47	39.20	3.00	.02	5,680.00
BLS23	750.40	149.28	5.02	96.40	7.78	.35	2,144.00
BLS33	610.00	80.40	7.58	30.00	20.33	.00	*
BLS37	656.85	124.80	5.26	32.40	20.27	.02	32,842.50
BLS43	567.35	114.08	4.97	44.80	12.66	.01	56,735.80
CNT05	556.65	52.40	10.62	13.32	41.79	.00	*
CNT12	703.08	105.68	6.65	7.60	92.51	.36	1,953.00
FINISHING	584.28	78.56	7.43	110.40	5.29	3.27	178.67
MC09	631.80	98.40	6.42	102.00	6.19	.04	15,795.00
MC15	660.60	60.48	10.92	23.60	27.99	.01	66,060.00
MC16	574.20	126.00	4.55	34.00	16.88	.00	*
MC18	928.80	108.40	8.56	130.40	7.12	.01	92,880.00
MC21	497.35	171.20	2.90	36.00	13.81	.00	*
MC23	280.12	114.40	2.44	32.00	8.75	.01	28,012.00
MC29	434.73	162.80	2.67	16.80	25.87	.00	*
MC45	558.28	58.56	9.53	311.60	1.79	.04	13,957.00
MISNOUS	505.56	170.88	2.95	10.00	50.55	.39	1,296.30
POLE06	443.30	80.40	5.51	18.76	23.63	.00	*
POLE15	745.80	108.40	6.88	22.00	33.90	.00	*
PRS09	595.20	122.00	4.87	130.00	4.57	.00	*
PRS14	623.45	130.80	4.76	176.00	3.54	.34	1,833.67
PRS15	506.30	142.00	3.56	89.60	5.65	.03	16,876.66
PRS17	586.50	82.88	7.07	36.80	15.93	.01	58,650.00
PRS19	399.60	81.20	4.92	18.00	22.20	.00	*
PRS23	1,330.00	92.40	14.39	60.80	21.87	.19	7,000.00
PRS40	603.22	76.48	7.88	3.96	152.32	.26	2,320.07
SPN07	19.60	84.96	.23	51.60	.37	.03	653.33
SPN09	562.40	108.40	5.18	63.20	8.89	.27	2,082.96
SPN10	518.31	76.00	6.81	17.00	30.48	.00	*
SPN12	103.70	71.04	1.45	36.00	2.88	.00	*
SPN15	19.05	76.00	.25	35.20	.54	.02	952.50
SPN23	773.95	84.00	9.21	24.00	32.24	.02	38,697.50

P/* LPTYVALL OUT (LABOR PRODUCTIVITY PERFORMANCE)
LBPR: LABOR PRODUCTIVITY.
GROWTH LAST: PRODUCTIVITY GROWTH OVER LAST PERIOD.
GROWTH BASE: PRODUCTIVITY GROWTH OVER BASE PERIOD.

08/22/82 LABOR PRODUCTIVITY MEASURES

WORK UNIT	TOTAL VALUE ADDED ($)	LABOR INPUT($)	LBPR	LAST LBPR	GROWTH LAST	BASE LBPR	GROWTH BASE
PLANT	121,188.20	5,810.62	20.85				
FABRICATN	99,388.20	3,252.98	30.55				
PRODUCT	21,800.00	1,253.42	17.39				
SERVICE	.00	978.50	.00				
BALLAST	40,448.52	970.64	41.67				
FINISHING	4,335.66	78.56	55.18				
MACHINE	34,206.27	900.24	37.99				
PRESS	13,162.96	727.76	18.08				
SPINNING	7,234.79	500.40	14.45				
ASSEMBLY1	2,073.08	139.84	14.82				
ASSEMBLY2	775.78	454.88	1.70				
CENTRAL	13,838.74	158.08	87.54				
MISNOUS	4,835.94	170.88	28.30				
POLE	276.46	188.80	1.46				
BLS03	9,558.30	138.80	68.86				
BLS07	9,146.52	70.80	129.18				
BLS11	128.70	66.40	1.93				

BLS12	46.07	79.60	.57
BLS15	615.37	66.88	9.20
BLS17	5,406.56	79.60	67.92
BLS19	.00	.00	*
BLS23	2,252.39	149.28	15.08
BLS33	2,718.80	80.40	33.81
BLS37	8,283.19	124.80	66.37
BLS43	2,292.62	114.08	20.09
CNT05	3,906.88	52.40	74.55
CNT12	9,931.86	105.68	93.98
MC09	2,025.90	98.40	20.58
MC15	7,180.14	60.48	118.71
MC16	4,785.60	126.00	37.98
MC17	.00	.00	*
MC18	7,195.50	108.40	66.37
MC21	4,023.85	171.20	23.50
MC23	3,702.65	114.40	32.36
MC29	3,451.28	162.80	21.19
MC45	1,841.35	58.56	31.44
POLE06	98.05	80.40	1.21
POLE15	178.41	108.40	1.64
PRS09	712.00	122.00	5.83
PRS12	.00	.00	*
PRS14	5,778.66	130.80	44.17
PRS15	162.87	142.00	1.14
PRS17	605.50	82.88	7.30
PRS19	4,644.00	81.20	57.19
PRS23	574.28	92.40	6.21

PRS40	685.65	76.48	8.96
SPN07	6.80	84.96	.08
SPN09	333.80	108.40	3.07
SPN10	624.03	76.00	8.21
SPN12	27.75	71.04	.39
SPN14	.00	.00	*
SPN15	298.55	76.00	3.92
SPN23	5,943.86	84.00	70.76

P/* CPTYVALL OUT (CAPITAL PRODUCTIVITY PERFORMANCE)
CAPR: CAPITAL PRODUCTIVITY.
LAST CAPR: PRODUCTIVITY OF LAST PERIOD.
GROWTH LAST: PRODUCTIVITY GROWTH OVER LAST PERIOD.

08/22/82 CAPITAL PRODUCTIVITY MEASURES

WORK UNIT	TOTAL VALUE ADDED ($)	CAPITAL INPUT($)	CAPR	LAST CAPR	GROWTH LAST	BASE CAPR	GROWTH BASE
PLANT	121,188.20	4,224.88	28.68				
FABRICATN	99,388.20	3,160.58	31.44				
PRODUCT	21,800.00	370.38	58.85				
SERVICE	.00	17.92	.00				
BALLAST	40,448.52	928.92	43.54				
FINISHING	4,335.66	110.40	39.27				
MACHINE	34,206.27	725.10	47.17				
PRESS	13,162.96	945.36	13.92				
SPINNING	7,234.79	378.20	19.12				

ASSEMBLY1	2,073.08	103.20	20.08
ASSEMBLY2	775.78	18.40	42.16
CENTRAL	13,838.74	83.64	165.45
CENTRAL	13,838.74	83.64	165.45
MISNOUS	4,835.94	10.00	483.59
POLE	276.46	55.14	5.01
BLS03	9,558.30	23.60	405.01
BLS07	9,146.52	39.20	233.32
BLS11	128.70	16.92	7.60
BLS12	46.07	209.20	.22
BLS15	615.37	324.80	1.89
BLS17	5,406.56	39.20	137.92
BLS19	.00	36.40	.00
BLS23	2,252.39	96.40	23.36
BLS33	2,718.80	30.00	90.62
BLS37	8,283.19	32.40	255.65
BLS43	2,292.62	44.80	51.17
CNT05	3,906.88	13.32	293.30
CNT12	9,931.86	7.60	,306.82
MC09	2,025.90	102.00	19.86
MC15	7,180.14	23.60	304.24
MC16	4,785.60	34.00	140.75
MC17	.00	35.20	.00
MC18	7,195.50	130.40	55.18
MC21	4,023.85	36.00	111.77
MC23	3,702.65	32.00	115.70
MC29	3,451.28	16.80	205.43
MC45	1,841.35	311.60	5.90

POLE06	98.05	18.76	5.22
POLE15	178.41	22.00	8.10
PRS09	712.00	130.00	5.47
PRS12	.00	424.20	.00
PRS14	5,778.66	176.00	32.83
PRS15	162.87	89.60	1.81
PRS17	605.50	36.80	16.45
PRS19	4,644.00	18.00	258.00
PRS23	574.28	60.80	9.44
PRS40	685.65	3.96	173.14
SPN07	6.80	51.60	.13
SPN09	333.80	63.20	5.28
SPN10	624.03	17.00	36.70
SPN12	27.75	36.00	.77
SPN14	.00	50.00	.00
SPN15	298.55	35.20	8.48
SPN23	5,943.86	24.00	247.66

P/* LPTYVALL OUT (LABOR PRODUCTIVITY PERFORMANCE)
ENPR: ENERGY PRODUCTIVITY.
GROWTH LAST: PRODUCTIVITY GROWTH OVER LAST PERIOD.
GROWTH BASE: PRODUCTIVITY GROWTH OVER BASE PERIOD.

08/22/82 LABOR PRODUCTIVITY MEASURES

WORK UNIT	TOTAL VALUE ADDED ($)	ENERGY INPUT($)	ENPR	LAST ENPR	GROWTH LAST	BASE ENPR	GROWTH BASE
PLANT	121,188.20	341.58	354.78				

FABRICATN	99,388.20	21.76	4,567.47
PRODUCT	21,800.00	185.43	117.56
SERVICE	.00	98.33	.00
BALLAST	40,448.52	4.82	8,391.80
FINISHING	4,335.66	3.27	1,325.88
MACHINE	34,206.27	.81	42,229.98
PRESS	13,162.96	3.07	4,287.60
SPINNING	7,234.79	5.84	1,238.83
ASSEMBLY1	2,073.08	45.56	45.50
ASSEMBLY2	775.78	.03	25,859.33
CENTRAL	13,838.74	11.07	1,250.11
MISNOUS	4,835.94	.39	12,399.84
POLE	276.46	120.14	2.30
BLS03	9,558.30	.03	*
BLS07	9,146.52	.10	91,465.20
BLS11	128.70	.01	12,870.00
BLS12	46.07	.00	*
BLS15	615.37	.00	*
BLS17	5,406.56	.02	*
BLS19	.00	.02	.00
BLS23	2,252.39	.35	6,435.40
BLS33	2,718.80	.00	*
BLS37	8,283.19	.02	*
BLS43	2,292.62	.01	*
CNT05	3,906.88	.00	*
CNT12	9,931.86	.36	27,588.50
MC09	2,025.90	.04	50,647.50

MC15	7,180.14	.01	*
MC16	4,785.60	.00	*
MC17	.00	.70	.00
MC18	7,195.50	.01	*
MC21	4,023.85	.00	*
MC23	3,702.65	.01	*
MC29	3,451.28	.00	*
MC45	1,841.35	.04	46,033.75
POLE06	98.05	.00	*
POLE15	178.41	.00	*
PRS09	712.00	.00	*
PRS12	.00	.44	.00
PRS14	5,778.66	.34	16,996.05
PRS15	162.87	.03	5,429.00
PRS17	605.50	.01	60,550.00
PRS19	4,644.00	.00	*
PRS23	574.28	.19	3,022.52
PRS40	685.65	.26	2,637.11
SPN07	6.80	.03	226.66
SPN09	333.80	.27	1,236.29
SPN10	624.03	.00	*
SPN12	27.75	.00	*
SPN14	.00	.01	.00
SPN15	298.55	.02	14,927.50
SPN23	5,943.86	.02	*

P/* PPTYVALL OUT (PARTIAL PRODUCTIVITY MEASURED IN $/$)
LBPR: LABOR PRODUCTIVITY

CAPR: CAPITAL PRODUCTIVITY
ENPR: ENERGY PRODUCTIVITY

08/22/82 PARTIAL PRODUCTIVITY MEASURES

WORK UNIT	VALUE ADDED ($)	LABOR INPUT	LBPR	CAPITAL INPUT	CAPR	ENERGY INPUT	ENPR
ASSMEBLY1	2,073.08	139.84	14.82	103.20	20.08	45.56	45.50
ASSEMBLY2	775.78	454.88	1.70	18.40	42.16	.03	25,859.33
BALLAST	40,448.52	970.64	41.67	928.92	43.54	4.82	8,391.80
BLS03	9,558.30	138.80	68.86	23.60	405.01	.03	*
BLS07	9,146.52	70.80	129.18	39.20	233.32	.10	91,465.20
BLS11	128.70	66.40	1.93	16.92	7.60	.01	12,870.00
BLS12	46.07	79.60	.57	209.20	.22	.00	*
BLS15	615.37	66.88	9.20	324.80	1.89	.00	*
BLS17	5,406.56	79.60	67.92	39.20	137.92	.02	*
BLS19	.00	.00	*	36.40	.00	.02	.00
BLS23	2,252.39	149.28	15.08	96.40	23.36	.35	6,435.40
BLS33	2,718.80	80.40	33.81	30.00	90.62	.00	*
BLS37	8,283.19	124.80	66.37	32.40	255.65	.02	*
BLS43	2,292.62	114.08	20.09	44.80	51.17	.01	*
CENTRAL	13,838.74	158.08	87.54	83.64	165.45	11.07	1,250.11
CNT05	3,906.88	52.40	74.55	13.32	293.30	.00	*
CNT12	9,931.86	105.68	93.98	7.60	1,306.82	.36	27,588.50
FABRICATN	99,388.20	3,252.98	30.55	3,160.58	31.44	21.76	4,567.47
FINISHING	4,335.66	78.56	55.18	110.40	39.27	3.27	1,325.88
MACHINE	34,206.27	900.24	37.99	725.10	47.17	.81	42,229.96
MC09	2,025.90	98.40	20.58	102.00	19.86	.04	50,647.50
MC15	7,180.14	60.48	118.71	23.60	304.24	.01	*
MC16	4,785.60	126.00	37.98	34.00	140.75	.00	*
MC17	.00	.00	*	35.20	.00	.70	.00

MC18	7,195.50	108.40	66.37	130.40	55.18	.01	*
MC21	4,023.85	171.20	23.50	36.00	111.77	.00	*
MC23	3,702.65	114.40	32.36	32.00	115.70	.01	*
MC29	3,451.28	162.80	21.19	16.80	205.43	.00	*
MC45	1,841.35	58.56	31.44	311.60	5.90	.04	46,033.75
MISNOUS	4,835.94	170.88	28.30	10.00	483.59	.39	12,599.84
PLANT	121,188.20	5,810.62	20.85	4,224.88	28.68	341.58	354.78
POLE	276.46	188.80	1.46	55.14	5.01	120.14	2.50
POLE06	98.05	80.40	1.21	18.76	5.22	.00	*
POLE15	178.41	108.40	1.64	22.00	3.10	.00	*
PRESS	13,162.96	727.76	18.08	945.36	13.92	3.07	4,287.60
PRODUCT	21,800.00	1,253.42	17.39	370.38	58.65	185.43	117.56
PRS09	712.00	122.00	5.83	130.00	5.47	.00	*
PRS12	.00	.00	*	424.20	.00	.44	.00
PRS14	5,778.66	130.80	44.17	176.00	32.83	.34	16,996.05
PRS15	162.87	142.00	1.14	89.60	1.81	.03	5,429.00
PRS17	605.50	82.88	7.30	36.80	16.45	.01	60,550.00
PRS19	4,644.00	81.20	57.19	18.00	258.00	.00	*
PRS23	574.28	92.40	6.21	60.80	9.44	.19	3,022.52
PRS40	685.65	76.48	8.96	3.96	173.14	.26	2,637.11
SERVICE	.00	978.50	.00	17.92	.00	98.33	.00

P/* PTYTALL OUT (TOTAL TIME PRODUCTIVITY MEASURED IN %)

08/22/82 TOTAL TIME PRODUCTIVITY MEASURES

WORK UNIT	LEVEL OF WORK UNIT	TOTAL TIME PRODUCTIVITY(%)
ASSEMBLY1	2	132.11
ASSEMBLY2	2	110.06
BALLAST	2	92.67
BLS03	1	61.78

BLS07	1	137.92
BLS11	1	102.12
BLS12	1	15.50
BLS15	1	108.77
BLS17	1	24.49
BLS19	1	.00
BLS23	1	156.33
BLS33	1	127.08
BLS37	1	136.84
BLS43	1	118.19
CENTRAL	2	95.99
CNT05	1	115.96
CNT12	1	146.47
FABRICATN	3	95.46
FINISHING	2	121.72
MACHINE	2	118.45
MC09	1	131.62
MC15	1	137.62
MC16	1	119.62
MC17	1	.00
MC18	1	193.49
MC21	1	103.61
MC23	1	58.35
MC29	1	90.56
MC45	1	116.30
MISNOUS	2	105.32
PLANT	4	74.89
POLE	2	80.80
POLE06	1	92.35
POLE15	1	155.37
PRESS	2	102.06
PRODUCT	3	90.08

PRS09	1	124.00
PRS12	1	.00
PRS14	1	129.88
PRS15	1	105.47
PRS17	1	122.18
PRS19	1	83.25
PRS23	1	277.08
PRS40	1	125.66
SERVICE	3	.00
SPINNING	2	57.55
SPN07	1	4.08
SPN09	1	117.16
SPN10	1	107.98
SPN12	1	21.60
SPN14	1	.00
SPN15	1	3.96
SPN23	1	161.23

P/* PTYTIO OUT (TOTAL TIME ADDED FOR NON-STANDARD PRODUCTS)
08/22/82

WORK UNIT	ADDED TIME(MINUTES)
BLS07	434.10
CNT05	578.80
SPN09	488.80

P/* PTYVALL OUT (TOTAL FACTOR PRODUCTIVITY MEASURED IN $/$)
08/22/82 TOTAL PRODUCTIVITY MEASURES

WORK UNIT	TOTAL VALUE ADDED ($)	TOTAL VALUE INPUT ($)	TOTAL FACTOR PRODUCTIVITY
ASSEMBLY1	2,073.08	288.60	7.18
ASSEMBLY2	775.78	473.31	1.63
BALLAST	40,448.52	1,904.38	21.23
BLS03	9,558.30	162.43	58.84
BLS07	9,146.52	110.10	83.07
BLS11	128.70	83.33	1.54
BLS12	46.07	288.80	.15
BLS15	615.37	391.68	1.57
BLS17	5,406.56	118.82	45.50
BLS19	.00	36.42	.00
BLS23	2,252.39	246.03	9.15
BLS33	2,718.80	110.40	24.62
BLS37	8,283.19	157.22	52.68
BLS43	2,292.62	158.89	14.42
CENTRAL	13,838.74	252.79	54.74
CNT05	3,906.88	65.72	59.44
CNT12	9,931.86	113.64	87.39
FABRICATN	99,388.20	6,435.32	15.44
FINISHING	4,335.66	192.23	22.55
MACHINE	34,206.27	1,626.15	21.03
MC09	2,025.90	200.44	10.10
MC15	7,180.14	84.09	85.38
MC16	4,785.60	160.00	29.91
MC17	.00	35.90	.00
MC18	7,195.50	238.81	30.13
MC21	4,023.85	207.20	19.42
MC23	3,702.65	146.41	25.28
MC29	3,451.28	179.60	19.21
MC45	1,841.35	370.20	4.97

MISNOUS	4,835.94	181.27	26.67
PLANT	121,188.20	10,377.08	11.67
POLE	276.46	364.08	.75
POLE06	98.05	99.16	.98
POLE15	178.41	130.40	1.36
PRESS	13,162.96	1,676.19	7.85
PRODUCT	21,800.00	1,809.23	12.04
PRS09	712.00	252.00	2.82
PRS12	.00	424.64	.00
PRS14	5,778.66	307.14	18.81
PRS15	162.87	231.63	.70
PRS17	605.50	119.69	5.05
PRS19	4,644.00	99.20	46.81
PRS23	574.28	153.39	3.74
PRS40	685.65	80.70	8.49
SERVICE	.00	1,094.75	.00
SPINNING	7,234.79	884.44	8.18
SPN07	6.80	136.59	.04
SPN09	333.80	171.87	1.94
SPN10	624.03	93.00	6.71
SPN12	27.75	107.04	.25
SPN14	.00	50.01	.00
SPN15	298.55	111.22	2.68
SPN23	5,943.86	108.02	55.02

P/* PTYVID OUT (VALUE ADDED FOR NON-STANDARD PRODUCTS)
08/22/82 VALUE ADDED ($)

WORK UNIT	VALUE ADDED

BLS07	$698.40
CNT05	931.20
SPN09	215.20

P/* SPV OUT (PARTIAL INPUT VALUE OF WORK UNITS)

08/22/82 PARTIAL INPUT VALUE (WORK UNIT ONLY)

WORK UNIT	LABOR($)	CAPITAL($)	ENERGY($)
ASSEMBLY1	139.84	103.20	45.56
ASSEMBLY2	454.88	18.40	.03
BALLAST	.00	36.00	4.26
BLS03	138.80	23.60	.03
BLS07	70.80	39.20	.10
BLS11	66.40	16.92	.01
BLS12	79.60	209.20	.00
BLS15	66.88	324.80	.00
BLS17	79.60	39.20	.02
BLS19	.00	36.40	.02
BLS23	149.28	96.40	.35
BLS33	80.40	30.00	.00
BLS37	124.80	32.40	.02
BLS43	114.08	44.80	.01
CENTRAL	.00	62.72	10.71
CNT05	52.40	13.32	.00
CNT12	105.68	7.60	.36
FABRICATN	75.38	72.60	3.95
FINISHING	78.56	110.40	3.27
MACHINE	.00	3.50	.00
MC09	98.40	102.00	.04
MC15	60.48	23.60	.01

MC16	126.00	34.00	.00
MC17	.00	35.20	.70
MC18	108.40	130.40	.01
MC21	171.20	36.00	.00
MC23	114.40	32.00	.01
MC29	162.80	16.80	.00
MC45	58.56	311.60	.04
MISNOUS	170.88	10.00	.39
PLANT	325.72	676.00	36.06
POLE	.00	14.38	120.14
POLE06	80.40	18.76	.00
POLE15	108.40	22.00	.00
PRESS	.00	6.00	1.80
PRODUCT	140.94	100.00	8.24
PRS09	122.00	130.00	.00
PRS12	.00	424.20	.44
PRS14	130.80	176.00	.34
PRS15	142.00	89.60	.03
PRS17	82.88	36.80	.01
PRS19	81.20	18.00	.00
PRS23	92.40	60.80	.19
PRS40	76.48	3.96	.26
SERVICE	978.50	17.92	98.33
SPINNING	.00	101.20	5.49
SPN07	84.96	51.60	.03
SPN09	108.40	63.20	.27
SPN10	76.00	17.00	.00
SPN12	71.04	36.00	.00
SPN14	.00	50.00	.01
SPN15	76.00	35.20	.02
SPN23	84.00	24.00	.02

P/* STV OUT (TOTAL INPUT VALUE OF WORK UNITS)
08/22/82 TOTAL INPUT VALUE (WORK UNIT ONLY)

WORK UNIT	VALUE($)
ASSEMBLY1	288.60
ASSEMBLY2	473.31
BALLAST	40.26
BLS03	162.43
BLS07	110.10
BLS11	83.33
BLS12	288.80
BLS15	391.68
BLS17	118.82
BLS19	36.42
BLS23	246.03
BLS33	110.40
BLS37	157.22
BLS43	158.89
CENTRAL	73.43
CNT05	65.72
CNT12	113.64
FABRICATN	151.93
FINISHING	192.23
MACHINE	3.50
MC09	200.44
MC15	84.09
MC16	160.00
MC17	35.90
MC18	238.81
MC21	207.20

MC23	146.41
MC29	179.60
MC45	370.20
MISNOUS	181.27
PLANT	1,037.78
POLE	134.52
POLE06	99.16
POLE15	130.40
PRESS	7.80
PRODUCT	249.18
PRS09	252.00
PRS12	424.64
PRS14	307.14
PRS15	231.63
PRS17	119.69
PRS19	99.20
PRS23	153.39
PRS40	80.70
SERVICE	1,094.75
SPINNING	106.69
SPN07	136.59
SPN09	171.87
SPN10	93.00
SPN12	107.04
SPN14	50.01
SPN15	111.22
SPN23	108.02

P/* TADD OUT (TIME PRODUCTIVITY OF BASIC WORK UNITS)
08/22/82 TIME PRODUCTIVITY MEASURES(%)

WORK UNIT	TIME ADDED(MIN)	TIME PROD(%)	INPUT LABOR TIME(MIN)	LABOR PROD(%)	INPUT MACHINE TIME(MIN)	MACHINE PROD(%)
ASSEMBLY1	634.150	132.11	581.680	121.18	523.160	108.99
ASSEMBLY2	528.300	110.06	436.650	90.96	470.250	97.96
BLS03	296.580	61.78	293.460	61.13	263.300	54.85
BLS07	662.040	137.92	609.120	126.90	648.000	135.00
BLS11	490.200	102.12	549.000	114.37	567.000	118.12
BLS12	74.400	15.50	72.000	15.00	74.400	15.50
BLS15	522.120	108.77	478.560	99.70	516.720	107.65
BLS17	117.600	24.50	72.000	15.00	105.600	22.00
BLS23	750.400	156.33	558.880	116.43	570.080	118.76
BLS33	610.000	127.08	519.200	108.16	568.400	118.41
BLS37	656.850	136.84	620.600	129.29	566.950	118.11
BLS43	567.358	118.19	535.942	111.65	553.520	115.31
CNT05	556.650	115.96	497.700	103.68	457.200	95.25
CNT12	703.080	146.47	669.060	139.38	646.380	134.66
FINISHING	584.280	121.72	566.460	118.01	542.700	113.06
MC09	631.800	131.62	594.300	123.81	569.400	118.62
MC15	660.600	137.62	548.100	114.18	554.400	115.50
MC16	574.200	119.62	467.400	97.37	495.600	103.25
MC18	928.800	193.50	868.500	180.93	872.100	181.68
MC21	497.350	103.61	487.600	101.58	462.400	96.33
MC23	280.120	58.35	207.110	43.14	186.250	38.80
MC29	434.730	90.56	434.730	90.56	434.730	90.56
MC45	558.280	116.30	524.000	109.16	527.200	109.83
MISNOUS	505.560	105.32	495.720	103.27	475.040	98.96
POLE06	443.300	92.35	425.650	88.67	425.100	88.56
POLE15	745.800	155.37	656.400	136.75	608.400	126.75
PRS09	595.200	124.00	556.800	116.00	529.600	110.33
PRS14	623.450	129.88	550.930	114.77	525.030	109.38
PRS15	506.300	105.47	503.900	104.97	485.600	101.16

PRS17	586.500	122.18	473.500	98.64	507.000	105.62
PRS19	399.600	83.25	397.800	82.87	273.600	57.00
PRS23	1,330.000	277.08	1,309.100	272.72	1,105.800	230.37
PRS40	603.220	125.67	521.420	108.62	516.470	107.59
SPN07	19.600	4.08	19.600	4.08	18.400	3.83
SPN09	562.400	117.16	550.400	114.66	470.400	98.00
SPN10	518.310	107.98	491.310	102.35	243.870	50.80
SPN12	103.700	21.60	123.700	25.77	117.800	24.54
SPN15	19.050	3.96	13.950	2.90	18.800	3.91
SPN23	773.950	161.23	580.750	120.98	527.850	109.96

P/* UTYALL OUT (MACHINE AND LABOR UTILIZATION)
08/22/82 MACHINE UTILIZATION

MACHINE	UTILIZED HRS	UTILIZATION(%)
71X773	7.833	97.912
74A532	9.045	113.062
75X457	7.917	98.962
77L231	4.455	55.687
77L321	10.140	126.750
77M511	8.717	108.962
77X256	7.619	95.237
77X323	10.773	134.662
81L097	4.560	57.000
81L419	3.104	38.800
81L421	8.607	107.587
81L423	7.023	87.787
81L427	11.852	148.150
81L431	.560	7.000
81L432	4.064	50.800

81L433	1.963	24.537
81L437	8.260	103.250
81L500	.000	.000
81L526	9.448	118.100
81L527	9.473	118.412
81L531	1.408	17.600
81L533	7.840	98.000
81L536	.000	.000
81L559	5.001	62.512
81L633	9.607	120.087
81L635	.000	.000
81L691	3.194	39.925
81L693	7.705	96.312
81L707	18.430	230.375
81L713	7.839	97.987
81L727	1.661	20.762
81L732	.000	.000
81L778	8.796	109.950
81L783	4.387	54.837
81L788	.306	3.825
81L833	10.078	125.975
81L844	.719	8.987
81L851	.510	6.375
81L855	9.240	115.500
81L857	.000	.000
81L883	.000	.000
81L923	8.826	110.325
81L931	.313	3.912
81L933	9.450	118.125
81L957	8.449	105.612
81L981	.000	.000
81L983	10.372	129.650

81L987	7.245	90.562
81L991	1.240	15.500
81L993	14.534	181.675
81L995	5.556	69.450
81L997	2.256	28.200

08/22/82 LABOR UTILIZATION

EMPLOYEE	UTILIZED HRS	UTILIZATION(%)
007824299	.000	.000
009231567	9.180	114.750
011294234	.000	.000
012035568	.000	.000
012928824	.000	.000
019297862	10.940	136.750
039374153	.326	4.075
107290088	.000	.000
123392182	.000	.000
126320076	4.891	61.137
156621111	8.607	107.587
156723308	9.278	115.975
158288122	10.150	126.875
162062612	7.790	97.375
167254312	.000	.000
176320188	6.630	82.875
178215623	.000	.000
178697852	.000	.000
192922376	9.150	114.375
196966666	.000	.000

198882525	11.151	139.387
206090184	.000	.000
209247230	21.818	272.725
218190233	10.027	125.337
219005120	9.691	121.137
219045262	8.690	108.625
219674569	.000	.000
246420188	.000	.000
256364253	9.135	114.187
269395214	.000	.000
279026202	1.200	15.000
313190299	.000	.000
314900191	.000	.000
321187237	9.313	116.412
323033452	8.652	108.150
327500001	8.262	103.275
333290160	.000	.000
336245123	3.451	43.137
346562819	.000	.000
349270999	.000	.000
382522536	9.678	120.975
423997268	7.274	90.925
427293614	8.398	104.975
444142468	.232	2.900
453563236	.000	.000
456782156	9.441	118.012
467263234	8.188	102.350
509091767	7.245	90.562
513330122	.000	.000
513397467	2.061	25.762
525267654	14.472	180.900
542437329	7.891	98.637

555197767	4.574	57.175
630001256	10.343	129.287
666902354	11.450	143.125
732568818	.000	.000
736774236	8.294	103.675
737012854	9.173	114.662
762340088	8.124	101.550
782890108	9.176	114.700

P/* UTYPJ OUT (UTILIZATION PROJECTION OF MACHINE AND LABOR)

08/22/82 MACHINE WEEKLY PROJECTED UTILIZATION(%)

MACHINE	1ST WK	2ND WK	3RD WK	4TH WK	5TH WK	6TH WK
71X773	189.45	252.40	274.40	210.50	143.87	123.95
74A532	41.82	62.80	41.82	50.25	41.82	33.47
75X457	55.27	48.92	40.72	42.40	36.82	25.45
77L231	49.87	68.50	68.20	56.50	40.02	34.85
77L321	41.35	54.47	49.67	45.92	37.07	23.37
77M511	495.32	118.90	59.42	178.32	168.37	138.15
77X256	42.30	63.47	42.30	50.80	42.30	33.85
77X323	14.22	21.37	14.22	17.10	14.22	11.37
81L097	23.42	7.27	6.12	9.10	10.42	10.22
81L419	94.62	32.55	26.57	39.85	42.85	40.55
81L421	55.52	68.30	77.70	60.97	40.50	36.05
81L423	112.40	68.37	63.70	69.50	54.17	52.50
81L427	72.60	108.90	72.60	87.15	72.60	58.05
81L431	42.12	21.70	16.02	24.75	20.70	16.27
81L432	215.35	152.82	138.37	153.25	118.65	97.65
81L433	288.92	162.90	147.20	170.30	138.47	131.00
81L437	132.45	82.60	79.10	82.55	63.60	63.60

81L526	16.27	24.42	16.27	19.55	16.27	13.00
81L527	59.20	88.80	59.20	71.05	59.20	47.35
81L531	110.05	26.42	13.20	39.62	37.40	41.80
81L533	196.60	102.77	78.50	115.62	97.30	77.82
81L559	407.50	164.72	132.20	192.67	163.02	172.37
81L633	115.85	144.55	159.22	121.90	82.15	74.62
81L691	29.12	38.85	43.15	32.37	21.57	19.42
81L693	192.42	64.97	53.40	79.87	86.90	82.90
81L707	175.42	122.97	111.20	108.37	106.32	90.77
81L713	47.22	63.00	69.97	52.47	34.97	31.47
81L727	10.00	13.35	14.82	11.12	7.40	6.67
81L732	5.75	6.07	7.25	6.22	4.07	3.57
81L778	148.57	87.32	76.92	91.37	72.60	65.82
81L783	164.40	123.75	111.07	116.82	94.85	78.52
81L788	24.32	7.55	6.37	9.45	10.82	10.62
81L833	23.30	34.97	23.30	28.00	23.30	18.65
81L844	1.65	2.50	1.65	2.00	1.65	1.32
81L851	27.15	13.97	10.32	15.95	13.32	10.47
81L855	34.60	46.20	51.27	38.47	25.60	23.07
81L857	12.95	6.65	4.92	7.60	6.35	5.00
81L923	46.42	23.27	11.55	16.37	19.12	15.95
81L931	47.75	24.57	18.15	28.02	23.47	18.47
81L933	53.15	70.87	78.72	59.05	39.35	35.42
81L957	156.27	48.55	40.92	60.77	69.65	68.37
81L983	218.80	83.97	80.62	166.55	130.85	97.52
81L987	51.92	16.12	13.60	20.20	25.15	22.70
81L991	9.07	13.00	10.97	10.57	8.05	6.75
81L993	54.47	72.67	80.72	60.55	40.35	36.32
81L995	50.65	67.57	75.07	56.30	37.52	33.77
81L997	176.32	42.32	21.12	63.45	59.92	66.97

P/* VADD3 OUT (TOTAL VALUE ADDED)

08/22/82 TOTAL VALUE ADDED

WORK UNIT	VALUE ADDED($)
ASSEMBLY1	2,073.08
ASSEMBLY2	775.78
BALLAST	40,448.52
BLS03	9,558.30
BLS07	9,146.52
BLS11	128.70
BLS12	46.07
BLS15	615.37
BLS17	5,406.56
BLS19	.00
BLS23	2,252.39
BLS33	2,718.80
BLS37	8,283.19
BLS43	2,292.62
CENTRAL	13,838.74
CNT05	3,906.88
CNT12	9,931.86
FABRICATN	99,388.20
FINISHING	4,335.66
MACHINE	34,206.27
MC09	2,025.90
MC15	7,180.14
MC16	4,785.60
MC17	.00
MC18	7,195.50
MC21	4,023.85
MC23	3,702.65

MC29	3,451.28
MC45	1,841.35
MISNOUS	4,835.94
PLANT	121,188.20
POLE	276.46
POLE06	98.05
POLE15	178.41
PRESS	13,162.96
PRODUCT	21,800.00
PRS09	712.00
PRS12	.00
PRS14	5,778.66
PRS15	162.87
PRS17	605.50
PRS19	4,644.00
PRS23	574.28
PRS40	685.65
SERVICE	.00
SPINNING	7,234.79
SPN07	6.80
SPN09	333.80
SPN10	624.03
SPN12	27.75
SPN14	.00
SPN15	298.55
SPN23	5,943.86

Appendix F. Sample Program

```
//B1222SWC JOB 88888,OVERALL TOTAL VALUE OF ALL WORK UNITS
//* OTV CNTL (PROGRAM OF OVERALL TOTAL VALUE OF WORK UNITS)
//*  OTV IS THE SUM OF (1) STV OF WK UNIT ITSELF (2) STV OF
//*  ITS COMPONENT WK UNITS.
//*  A88888.OTV WAS CREATED (FILE20)
/*ROUTE PRINT VM2.INDENG28
/*LONGKEY XXXXX
/*JOBPARM       LINES=10
//*
//* OBTAIN GP ITSELF INTO TEMP1, SUB-GP INTO TEMP2
//*
//STEP1   EXEC  M4PSR
//M4P.M4LIB     DD  DSN=A88888.LIBRARY,DISP=SHR
//M4P.M4OLD     DD  DSN=A88888.GP,DISP=SHR
//M4P.M4SUBF1   DD  DSN=&&TEMP1,DISP=(NEW,PASS),
//  UNIT=SYSDA,SPACE=(TRK,10)
//M4P.M4SUBF2   DD  DSN=&&TEMP2,DISP=(NEW,PASS),
//  UNIT=SYSDA,SPACE=(TRK,10)
//M4P.SYSIN     DD *
S1      RCGP      S     S
S1      RFFILE20  SM4SUBF1
S1      RFFILE21  SM4SUBF2
S1      ERTODAY VINCENT SHU
S1      E1                           NR FILE20      F
S1      R1005  OGP-NO
S1      R1010  OLEVEL
S1      R1015  OGP-NO
S1      R1020  OOH
S1      E2                           NR FILE21      F
S1      R2005  OGP-NO
S1      R2010  OLEVEL
S1      R2015  OSUB-GP
```

```
//M4R.SYSIN DD *
S1       RC                    S
/*
//*
//* SORT TEMP2 INTO TEMP3 FOR SUB-GP
//*
//STEP2 EXEC SORTD,PARM='MSG=AP'
//SORTIN DD DSN=&&TEMP2,DISP=(OLD,DELETE)
/*
//SORTWK01 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK02 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK03 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK04 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK05 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK06 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTOUT DD DSN=&&TEMP3,DISP=(NEW,PASS),
//   SPACE=(TRK,3),UNIT=SYSDA
//SYSIN DD *
 SORT FIELDS=(11,9,CH,A)
 RECORD TYPE=F,LENGTH=50
 END
/*
//*
//* MATCH TEMP3 AND MOD INTO TEMP1, CREAT TEMP2 (SUB-GP)
//*
//STEP3  EXEC  M4PSR
//M4P.M4LIB     DD  DSN=A88888.LIBRARY,DISP=SHR
//M4P.M4OLD     DD  DSN=A88888.GP,DISP=SHR
//M4P.M4CORD1   DD  DSN=&&TEMP3,DISP=(OLD,DELETE)
//M4P.M4SUBF1   DD  DSN=&&TEMP1,DISP=(MOD,PASS)
//M4P.M4SUBF2   DD  DSN=&&TEMP2,DISP=(NEW,PASS),
//    UNIT=SYSDA,SPACE=(TRK,3)
```

```
//M4P.SYSIN    DD *
S1       RCGP       S      S
S1       RFFILE21   SM4CORD1
S1       RFFILE20   SM4SUBF1
S1       RFFILE21   SM4SUBF2
S1       ERTODAY VINCENT SHU
S1       PR005   1FACTOR   EQOGP-NO
S1       PR010             NS END
S1       E1                                  NR FILE20       F
S1       R1005   1GP-NO
S1       R1010   1LEVEL
S1       R1015   OGP-NO
S1       R1020   OOH
S1       E2                                  NR FILE21       F
S1       R2005   1GP-NO
S1       R2010   1LEVEL
S1       R2015   OSUB-GP
//M4R.SYSIN DD *
S        RC                S
/*
//*
//* SORT TEMP2 INTO TEMP3 FOR SUB-GP
//*
//STEP4 EXEC SORTD,PARM='MSG=AP'
//SORTIN DD DSN=&&TEMP2,DISP=(OLD,DELETE)
/*
//SORTWK01 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK02 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK03 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK04 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK05 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK06 DD UNIT=SYSDA,SPACE=(TRK,15)
```

```
//SORTOUT DD DSN=&&TEMP3,DISP=(NEW,PASS),
//   SPACE=(TRK,3),UNIT=SYSDA
//SYSIN DD *
 SORT FIELDS=(11,9,CH,A)
 RECORD TYPE=F,LENGTH=50
 END
/*
//*
//* OBTAINS SUB GP OF TEMP3 AND PUTS INTO TEMP2 MOD INTO TEMP1
//*
//STEP5  EXEC  M4PSR
//M4P.M4LIB     DD  DSN=A88888.LIBRARY,DISP=SHR
//M4P.M4OLD     DD  DSN=A88888.GP,DISP=SHR
//M4P.M4CORD1   DD  DSN=&&TEMP3,DISP=(OLD,DELETE)
//M4P.M4SUBF1   DD  DSN=&&TEMP1,DISP=(MOD,PASS)
//M4P.M4SUBF2   DD  DSN=&&TEMP2,DISP=(NEW,PASS),
//    UNIT=SYSDA,SPACE=(TRK,3)
//M4P.SYSIN     DD *
S1       RCGP      S      S
S1       RFFILE21  SM4CORD1
S1       RFFILE20  SM4SUBF1
S1       RFFILE21  SM4SUBF2
S1       ERTODAY VINCENT SHU
S1       PR005  1FACTOR  EQ0GP-NO
S1       PR010           NS END
S1       E1                                 NR FILE20      F
S1       R1005  1GP-NO
S1       R1010  1LEVEL
S1       R1015  0GP-NO
S1       R1020  0CH
S1       E2                                 NR FILE21      F
S1       R2005  1GP-NO
```

```
S1       R2010  1LEVEL
S1       R2015  0SUB-GP
//M4R.SYSIN DD *
S        RC                   S
/*
//*
//* SORT TEMP2 INTO TEMP3 FOR SUB-GP
//*
//STEP6 EXEC SORTD,PARM='MSG=AP'
//SORTIN DD DSN=&&TEMP2,DISP=(OLD,DELETE)
/*
//SORTWK01 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK02 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK03 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK04 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK05 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK06 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTOUT DD DSN=&&TEMP3,DISP=(NEW,PASS),
//   SPACE=(TRK,3),UNIT=SYSDA
//SYSIN DD *
 SORT FIELDS=(11,9,CH,A)
 RECORD TYPE=F,LENGTH=50
 END
/*
//*
//* OBTAINS SUB GP OF TEMP3 AND PUTS INTO TEMP2 MOD INTO TEMP1
//*
//STEP7  EXEC  M4PSR
//M4P.M4LIB     DD  DSN=A88888.LIBRARY,DISP=SHR
//M4P.M4OLD     DD  DSN=A88888.GP,DISP=SHR
//M4P.M4CORD1   DD  DSN=&&TEMP3,DISP=(OLD,DELETE)
//M4P.M4SUBF1   DD  DSN=&&TEMP1,DISP=(MOD,PASS)
```

```
//M4P.M4SUBF2  DD  DSN=&&TEMP2,DISP=(NEW,PASS),
//    UNIT=SYSDA,SPACE=(TRK,3)
//M4P.SYSIN    DD *
S1      RCGP      S     S
S1      RFFILE21  SM4CORD1
S1      RFFILE20  SM4SUBF1
S1      RFFILE21  SM4SUBF2
S1      ERTODAY VINCENT SHU
S1      PR005  1FACTOR  EQ0GP-NO
S1      PR010           NS END
S1      E1                                NR FILE20     F
S1      R1005  1GP-NO
S1      R1010  1LEVEL
S1      R1015  0GP-NO
S1      R1020  00H
S1      E2                                NR FILE21     F
S1      R2005  1GP-NO
S1      R2010  1LEVEL
S1      R2015  0SUB-GP
//M4R.SYSIN DD *
S       RC              S
/*
//*
//* SORT TEMP1 INTO TEMP4 FOR GP-NO
//*
//STEP8 EXEC SORTD,PARM='MSG=AP'
//SORTIN DD DSN=&&TEMP1,DISP=(OLD,DELETE)
/*
//SORTWK01 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK02 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK03 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK04 DD UNIT=SYSDA,SPACE=(TRK,15)
```

```
//SORTWK05 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTWK06 DD UNIT=SYSDA,SPACE=(TRK,15)
//SORTOUT DD DSN=&&TEMP4,DISP=(NEW,PASS),
//   SPACE=(TRK,10),UNIT=SYSDA
//SYSIN DD *
 SORT FIELDS=(1,9,CH,A)
 RECORD TYPE=F,LENGTH=50
 END
/*
//*
//*  STANDARD INPUT VALUE CALCULATION
//*
//STEP9  EXEC  M4PSR
//M4P.M4LIB     DD  DSN=A88888.LIBRARY,DISP=SHR
//M4P.M4OLD     DD  DSN=A88888.GP,DISP=SHR
//M4P.M4CORD1   DD  DSN=&&TEMP4,DISP=(OLD,DELETE)
//M4P.M4SUBF1   DD  DSN=A88888.OTV,DISP=(NEW,CATLG,DELETE),
//   UNIT=SYSDA,SPACE=(TRK,1),VOL=SER=USER04
//M4P.SYSIN     DD *
S1      RCGP       S     S
S1      RFFILE20   SM4CORD1 GP-NO
S1      RFFILE20   SM4SUBF1
S1      TFID       009C                          WORKING       UNIT
S1      TFLAST     009C                          WORKING       UNIT
S1      TFT-C      009Z2      0                  STANDARD      INPUT VALUE
S1      TFTOTAL    009Z2      0                  STANDARD      INPUT VALUE
S1      TFFILLER   010C
S1      ERTODAY VINCENT SHU
S1      PR005  1GP-NO     EQ0GP-NO
S1      PR010             NS END
S1      PR015  1GP-NO     EQTLAST
S1      PR020             NS 060
```

```
S1        PR025  TT-C       + 1INPUT                                TT-C
S1        PR030             GO END
S1        PR060             R TLAST                                 TID
S1        PR065             R 1GP-NO                                TLAST
S1        PR070             R TT-C                                  TTOTAL
S1        PR075             R 1INPUT                                TT-C
S1        PR080  TIC        NEC
S1        PR085             NS END
S1        E1                                  FILE20        F
S1        R1005  TID
S1        R1010  TFILLER
S1        R1015  TTOTAL
S2        ERTODAY VINCENT SHU                               E
S2        E1                                  FILE20        F
S2        R1005  TLAST
S2        R1010  TFILLER
S2        R1015  TT-C
//M4R.SYSIN DD *
S2        RC                S
/*
//
```

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A PRODUCTIVITY MEASUREMENT SYSTEM FOR MANUFACTURING PLANTS

by

Wen-Chieh Shu

(ABSTRACT)

A productivity monitoring system is developed to incorporate productivity measurement at various organizational levels within manufacturing plants into the general information system. Classical productivity measures, defined as ratios of inputs and outputs of production, are used in the developed system. In addition to measuring the total and partial productivity, the system compiles the total factor productivity which is often applied in manufacturing to represent operational efficiency.

In the developed system, reporting of productivity information is based on the organizational structure such that productivity measures are provided only when the corresponding organizational (work) units exist. Thus, the productivity monitoring system provides not only the responsibility-based productivity information, but is flexible in the aggregation of productivity performances of organizational units.

The system is executed on the MARK IV File Management System (Informatics Inc.), and a real-world case is studied. Since the data required in the productivity monitoring system are commonly available and shared by other manufacturing subsystems, the system can be implemented as a subsystem of the general information system.