Startup Management

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Abstract—The causes and consequences of disrupted startups of new product and production processes are examined in relation to examples drawn from several, diverse industries. It is demonstrated that inappropriate management actions can often precipitate significant deviations from expected patterns of productivity increases during startups, resulting in important short- and long-run productivity losses. Based upon the discussion, several guidelines for effective startup management are suggested.

INTRODUCTION

STARTUPS of new products and new production processes have been studied in various forms of mechanized and labor-intensive manufacturing since the introduction of the familiar learning curve concept in the aerospace industry several decades ago [1], [2], [6], [9]. Many of these studies have focused on the empirical derivation of models to estimate the productivity gains that accrue with increasing production experience during normal startups [1], [3], [13], [14]. Unfortunately, as operations manager in many industries know, not all startups are "normal." Some deviate appreciably from anticipated patterns of increasing productivity. An investigation of such "abnormal" startups is the subject of this paper. More specifically, we shall explore the apparent causes and productivity consequences of different types of interrupted startups and derive some guidelines for managing the startup phenomenon.

The importance of effective startup management is not always adequately appreciated. As a result, abnormal startups are often precipitated by injudicious management actions or practices, which can range from poor scheduling decisions to demoralizing compensation policies. The consequences of these actions are frequently serious. In some cases the momentum of a startup can be interrupted temporarily, causing irretrievable losses of productivity. Alternatively, startups may be permanently aborted at suboptimum levels of productivity, resulting in serious long-run implications. Chronic mismanagement of startups can ultimately have important motivational effects throughout a production facility—making startups a period of dreaded activity and resulting in significant resistance to product and process innovation.

The existence of these problems often betrays a poor understanding of the essential nature of startups. Most startups are periods of intense and difficult adaptation on the part of direct and indirect labor, engineering, and supervisory personnel. Their adaptive efforts often have a fragile momentum that can be disrupted easily; events that would have minor affects on productivity during steady-state operations can seriously interrupt or abort startups. The infrequency of startups in some companies also contributes to the difficulty of predicting the effects that "routine" changes in operating policies and procedures may have during a startup. Inexperience with startups can thus lead to inept startup management.

Several of the more common mistakes in startup management that we have encountered in different industries are explored in the main body of the paper. These fall into four major categories: 1) changes in product design and production factors; 2) discontinuous manufacturing policies; 3) provision of technical supervision and assistance; and 4) ineffective motivation and compensation programs. The discussion draws upon examples from situations in which the applicability of the "learning curve model" in describing normal startups has been documented, and deviations from this model are used to illustrate the productivity effects of various policies and actions.

LEARNING CURVE MODEL

It has been demonstrated that the following function provides an efficient description of the improvements in productivity or cost that occur during the normal "startup phase" of new product and process introductions in a variety of industries [1], [2], [4], [6]:

$$y = ax^b \qquad [1]$$

where y is an index of productivity or of product cost, x an index of cumulative product output, and a and b parameters of the model.

Logarithmic transformation of the model demonstrates the linearity of the startup phase when plotted on log coordinates:

$$\log y = \log a + b \log x. \qquad [2]$$

In labor-intensive forms of manufacture, y is usually defined as product or labor cost per unit, x is in units, and b assumes negative values in the range $-1 \leq b \leq 0$, making unit cost a *decreasing* function of cumulative output. In mechanized manufacture, y is defined as process productivity (e.g., tons per hour), x is in commensurate output terms (tons of output), and b assumes positive values in the range $0 \leq b \leq 1$, thus making productivity an *increasing* function of output. (Both formulations will be illustrated graphically later in the paper.) The a parameter theoretically represents the cost or pro-

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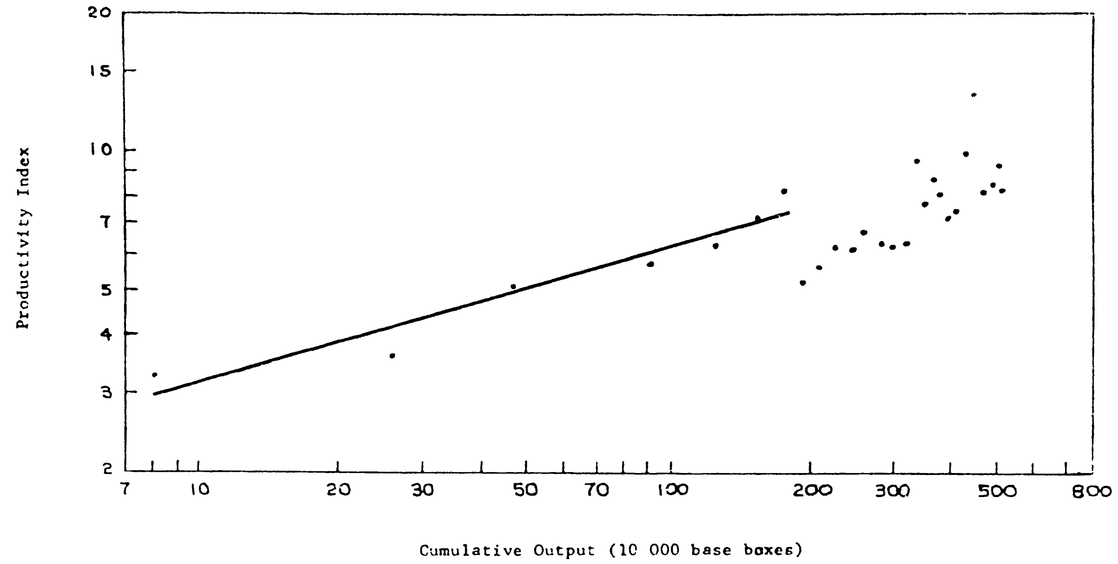

Fig. 1. Startup of temper mill.

ductivity at the first unit of output:

$$y = a(1)^b = a \qquad \text{for } x = 1. \qquad [3]$$

The productivity or cost improvements that define the startup phase terminate ultimately in a second "steady-state" or constant productivity phase in most forms of manufacture when cumulative production volume becomes large [2], [6]. This steady-state phase is not defined by the startup model (which postulates continuous improvement in cost or productivity as output continues to increase) and must therefore be estimated separately in practice.

CHANGES IN PRODUCT AND PRODUCTION FACTORS

Startups can be affected by abrupt changes in product mix, production design specifications, and a variety of production factors (e.g., raw material, manpower, supervision, tooling, etc.). In our experience, the disruptive effects of such modifications can be a function of their rate of change and the type of manufacture in which they occur. In many labor intensive forms of production, well-programmed and gradual modifications of these production variables are an integral part of the learning phenomenon [3], [9], whereas erratic or sudden changes can interrupt the overall adaptation effort. Process startups in some forms of machine-intensive production, on the other hand, can be more sensitive to changes in the "conditions of manufacture." Because of an intense concentration on mastering process variables and developing standard operating procedures, changes in product specifications and production factors may prove very disruptive during such startups.

An example of the potential consequences of product specification and mix changes is provided by the startup of a new temper mill in an integrated steel-manufacturing firm. Previous studies in this company had shown that startups typically conform to the startup model until the steady-state phase is reached [2]. However, after a normal beginning, the temper-mill startup deviated from the usual pattern. As can be seen in Fig. 1, it followed a log linear trend through the first 7 months of production, during which nearly 2 million "base boxes" of steel were produced (a base box is roughly 200 feet^2). In the eighth month, the productivity index[1] drops dramatically to some 60 percent of the previous level and then begins to increase slowly and irregularly over the next 20 months of manufacture (at which point this study ended).

This interruption of the startup was precipitated by a change in the mix of product being rolled on the mill. The first 7 months of production was limited to "hot rolled steel." The eighth month marked the introduction of "cold rolled steel," which required sufficiently different operating settings and procedures to confuse the entire *process* adaptation effort. The change resulted in a considerable disruption of the learning curve; following the interruption, production efficiency dropped on both product types and the overall productivity remained below previously attained levels for 8 months (and over 1 million base boxes of output).

Another example of the effects of changing product mix is provided by the labor-intensive production of wearing apparel. As in the steel industry, research has shown that startups of new "styles" or models of wearing apparel conform to the learning curve model under normal production procedures [6]. In this case, however, normal procedures were not observed. Three new styles of a basic type of apparel were introduced at different times on the same production line, whereas usually each processing line specialized in the production of only one style.

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[1] Productivity and cost indices, rather than actual productivity figures, have been used throughout the paper at the request of the participating companies.

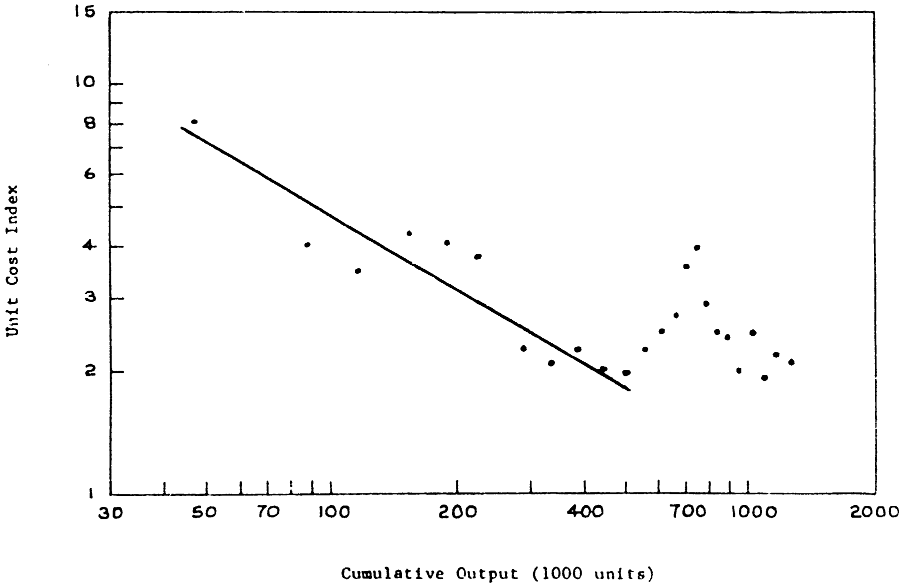

Fig. 2. Apparel startup.

The consequences of varying the product mix in this way are illustrated in Fig. 2, where the production history of the startup is summarized in relation to monthly measurements of the average unit cost index. The initial data points have been fitted to a least squares line for discussion purposes; the variations of the monthly data points about this line show the effects of the first and second style introductions. The first 3 months of the startup were devoted to the production of a single style, and the apparent trend of the three points was well *below* the regression line. When the second style was added in the fourth month, the data jumped above the line, remained there for 3 months, fell dramatically, and then showed a downward trend for the last 5 months of the regression line. The end of the line marked the introduction of the third garment style. The reaction was dramatic—costs drifted upward for 5 months until they ultimately doubled. The next 8 months of alternating production of all three styles was marked by a pronounced relearning phase that finally reduced costs to their previous level. The result: 15 months and 700 000 units of "high-cost" production following the introduction of the third style.

One may question the wisdom of changing product mix during this startup. Maintaining the policy of production specialization—even if it meant the creation of three smaller lines—could have been a more rational choice for the firm. Of course, the production managers had not expected such a violent reaction since the changes in style design and worker tasks seemed minor to them and each style was run in batches for several days, not intermingled chaotically. However, as in the steel case, the serious results indicate the necessity of understanding and evaluating the potential implications of what may appear to be minor changes in product mix during startups. Such "preproduction planning" may suggest other, less costly means of achieving the desired mix of product.

The literature on learning curve applications in the aerospace and electronic industries enables us to expand our examination of the types of manufacturing changes that can disrupt the adaptation process. Several authors have demonstrated that major modifications of product-design specifications and abrupt changes in production factors [facilities, tooling, process design, serial addition of direct labor personnel, etc.] can result in disruptions of the learning curves of new aircraft and electronic equipment [8]–[10], [15]. When changes are made in production factors, the deviations from the learning curve often take the form of a "hump" (or concavity) in the log linear trend [8]. Product design changes and facility relocations, on the other hand, can cause definite discontinuities in the learning curve similar to those illustrated above [9], [10].

The practice of making abrupt changes in manufacturing conditions during startups in these industries deserves further scrutiny. Although some changes are unavoidable—design modifications for different customers are an example—others may not be cost effective. For example, in addition to creating "humps" in the learning curve, sudden changes in production factors may also result in a slower rate of learning throughout the subsequent production history of a new product model. If this were the case, greater preproduction engineering and better production programming could transform such costly changes into gradual modifications that neither interrupt nor decrease the overall rate of adaptation.

Variations in another factor of production—raw material—can also disrupt the learning process in some industries. In extreme cases raw material changes can perturb a startup so greatly that systematic analysis of the learning phenomenon becomes difficult. This appears to be true in food-processing industries; our examinations of food-processing equipment startups have indicated that the extreme variance in the raw produce attributable to seasonal, geographical, and other variables affect productivity to such a degree that one cannot define a true learning curve. We have also observed definite, though less extreme, effects of raw material variations on the startups of highly mechanized processes in other industries. The steel industry is a good example. In recognition of the problem some plants actually preselect the material input to new processes during the startup period—essentially spoon feeding the baby in its infancy.

DISCONTINUOUS MANUFACTURING

From the previous discussion it can be inferred that discontinuous manufacture of a new product might disrupt the learning phenomenon. The significance of the effect, however, may come as an unpleasant shock to operating managers. Discontinuation of an initial "run" or "lot" of a new product can interrupt a startup and result in an appreciable and costly relearning phenomena during subsequent production runs.

In our experience these phenomena are more prevalent and pronounced in machine-intensive manufacture. The many interdependent operating variables that must be controlled simultaneously make these processes susceptible to a loss of startup momentum and control when production is discontinued. This tendency is accentuated when the interruption occurs before steady-state productivity levels are reached. The experimentation with operating variables that forms an essential part of a startup is aborted before machine crews and engineers have been able to document an efficient "standard operating practice." In subsequent runs, much of the trial-and-error experimentation may be repeated in order to develop the momentum and levels of productivity that had been attained previously.

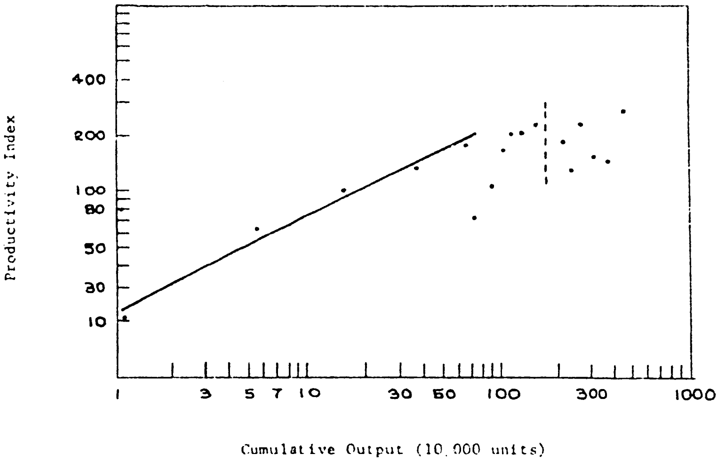

Fig. 3. Bulb startup.

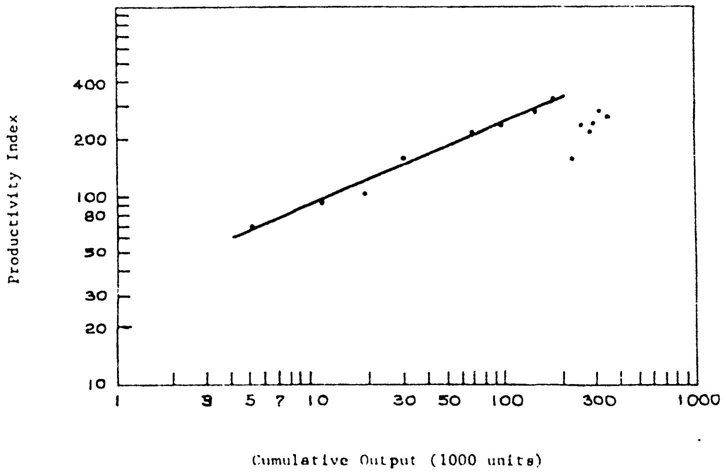

Fig. 4. Bulb startup.

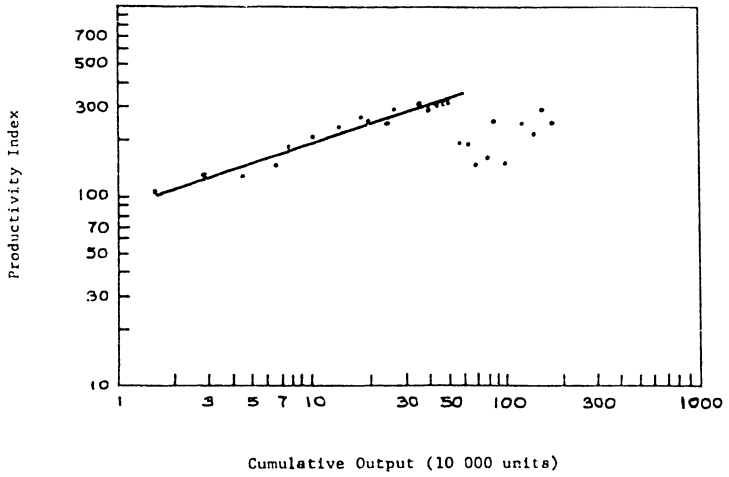

Fig. 5. Bulb startup.

The potential effects of discontinuous production in machine-intensive manufacture are illustrated vividly by the startups of new television bulbs (or "envelopes"). Although these startups typically conform to the learning curve model during initial production runs [2], the productivity patterns of subsequent runs behave very differently. The three cases shown in Figs. 3, 4, and 5 are representative. The production history shown in Fig. 3 can be divided into three segments. The first five points indicate the average productivity during the initial, 5-week production run (log linear regression line). Next, there is a pronounced relearning phase that occurred during the second 6-week run. Note that the average productivity during the first of the 6 weeks is less than 40 percent of that attained earlier and that it remains below this level for 3 weeks. During the last 3 weeks, however, productivity ultimately surpassed the first run level by an appreciable amount. The third segment appears to the right of the dotted line in the figure. Each of these data points represents the *average* productivity of six different production runs of less than 3-week duration. As can be seen, three of these runs exhibit productivities well below the previous highs; two were roughly comparable to previous levels; and the last run sets a new high.

Two important points emerge from this history. First, it is evident that discontinuation of the production runs resulted in a considerable interruption of the adaptation phenomenon in both the initial startup and the relearning phases. Secondly, the hypothetical "loss" of productivity incurred by following a discontinuous versus a continuous production policy was enormous. Perusal of Fig. 3 will indicate that nearly 200 000 units of product (40 percent of total output) was manufactured at average productivities substantially below the level attained at the end of the *fifth* week of the startup. If one assumes the startup phase would have continued and extrapolates the initial trend over the entire history,[2] it appears that the average productivity would have been approximately *twice* that which was actually achieved.

Both of these points are further illustrated in Fig. 4, which shows the history of a television bulb that had only two production runs. The first run of 8-week duration (log linear trend) was interrupted for 1 month and then resumed for 6 weeks (relearning phase). Productivity during the first week of the second run is again approximately one half of that achieved at the end of the first run. Unlike the previous case, however, maximum productivity during the second run does not eventually surpass the first run maximum.

Fig. 5 provides a dramatic demonstration of the productivity losses associated with a policy of scheduling many short production runs in this type of manufacture. Following an initial 16-week run (log linear phase), ten different runs of only 1–3 weeks duration were scheduled every 3–8 weeks. The ten data points to the right of the initial startup phase give the average productivity achieved during each of these runs. As can be seen, all of the data points fall below the maximum level of the first run and five of them are only 50–60 percent of this level.

These examples indicate the importance of considering relearning effects when formulating production scheduling policies. The total productivity "losses" associated with frequent interruptions of a startup may greatly outweigh inventory costs and other considerations, making a policy of longer and less frequent runs more economical. This point was clearly illustrated in the last example, where the frequent scheduling of very short production runs was extremely costly in productivity. The scheduling practices in this company were the joint product of a poor appreciation of the magnitude of relearning effects and an overly cautious inventory posture. Learning curve and productivity analyses can lead to a significant change in operating policies in such cases.

TECHNICAL SUPERVISION

It is generally conceded that industrial and manufacturing engineers play an important role in the adaptation or learning experience during virtually all startups [3], [9]. In addition, we often find that, as the sophistication and uniqueness of a new manufacturing process or new product increases, development and process design engineers also play a critical role in the success of a startup. The degree of technical innovation in these cases can exceed the ability of supervisors and manufacturing engineers to cope with it. Such startups really represent the final stage of an engineering development effort—not merely a reduction to efficient operating practice—and therefore demand the involvement of design and development engineers.

Innovations that depart substantially from previous operating experience are likely to benefit from the involvement of development engineers. A familiar example is the introduction of mechanization or automation in a manufacturing organization that has evolved around a less sophisticated production technology. It has been stated that the startups of mechanized and automated processes normally rely on the expertise of development engineers and that management recognition of this fact is critical to ensuring efficient adaptation [7]. If operating personnel are asked to cope with the complexities of such startups without the assistance of development engineers, or if this technical assistance is withdrawn prematurely, the results can be unfortunate.

An example of these results is provided by the startup of an automated process that was developed to assemble a high-tolerance electromechanical switching component. The process represented a distinct departure from the former hand assembly means of producing the component and automation was generally an unfamiliar mode of manufacturing to the operating managers in the plant. The company, being a leader in technological development, recognized the necessity of providing development engineering assistance during the startup; it did not, however, correctly anticipate the required duration of their involvement.

During the first 6 months of the startup, the development engineers assisted operating personnel in debugging the process. The results during this stage were most encouraging, as indicated by steady increases in productivity. At the end of 6 months, however, the process was released to operating personnel and the development engineers were reassigned. Difficulties developed immediately; the process began to run out of control and productivity declined steadily until the development engineers were brought back into the effort. With their reinvolvement, the problems were brought under control and productivity began climbing again, ultimately surpassing previous levels by a significant amount.

This production history is illustrated in Fig. 6, where each data point represents average productivity over a 2-week reporting period. The first 13 points (regression line) show the very rapid gains in productivity that were attained with the assistance of the development engineers during the first 6 months. The end of the trend coincides with the engineers reassignment. Productivity then eroded steadily throughout their 12-week absence.

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[2] Startup phases of considerably greater duration have actually been documented during prolonged initial runs in this firm [2].

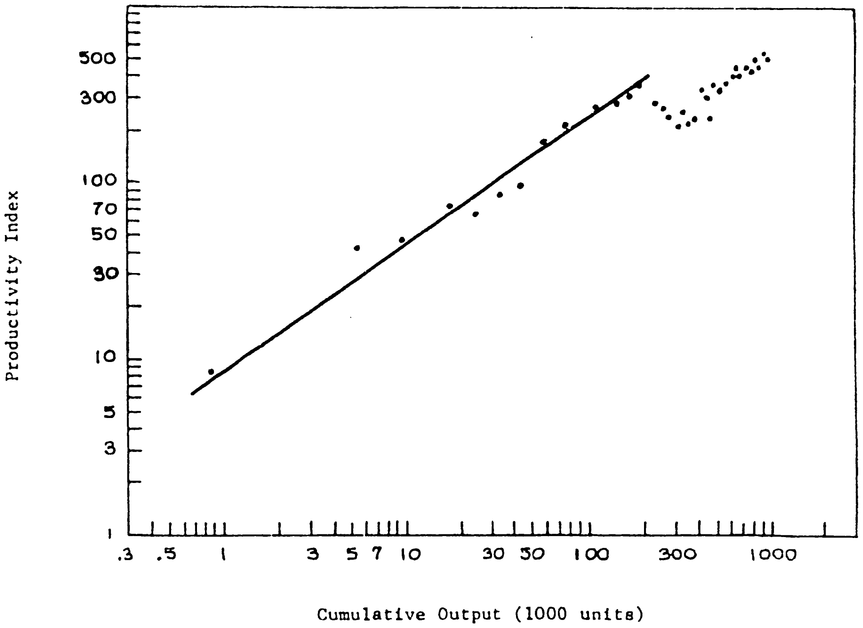

Fig. 6. Automated process startup.

Upon their return, productivity began to climb sharply again and had exceeded the earlier maximum by approximately 50 percent at the end of the available production data. Extrapolating the initial startup trend again indicates that the average productivity for the 44 weeks following the interruption would have been more than double that which was actually experienced. Given that some 800 thousand units were produced after the interruption, the "lost productivity" implications are clear.

In our experience, the importance of technical assistance during startups is not fully understood in many companies. On the other hand, some firms staff their startups with the required technical expertise as a matter of course. Others go further and actually assign "startup teams" of technical personnel with considerable experience to facilitate startups in different plants. This explicit recognition of the importance of experienced, technical supervision during startups could be emulated profitably by other companies.

Motivation and Compensation

The cooperative efforts of direct and indirect labor employees are critical to the achievement of efficient startups in most instances. In both labor and machine-intensive manufacture, labor resistance to innovations can slow or even abort product and process startups. A primary aspect of effective startup management, therefore, is motivating workers to accept startups and cooperate in the task of improving productivity.

One of the largest obstacles to eliciting these efforts in many companies is the inappropriate application of wage incentives during a startup. Too frequently, the incentive system acts as a strong negative motivator. In some cases, workers become concerned and demoralized over the ultimate task levels that they will be expected to achieve in order to maintain historical pay rates. In other cases, workers may take advantage of their influence on productivity to "bargain" informally for greater pay at a given level of effort. In either instance, the outcomes may be interrupted startups or startups that are permanently aborted at suboptimum productivity levels.

We draw upon three examples from the steel industry to illustrate the potential effects of incentive applications during startups. The industry selection is particularly appropriate. Steel has a long history of incentive wage applications and the cost implications of lost productivity in multi-million dollar steel processes can be very significant.

The first example concerns the startup of a continuous steel-finishing process. Interim standards and incentives were installed at the beginning of the startup and were maintained during the first 10 months of production. At the beginning of the eleventh month, management decided to tighten the interim standards and install permanent incentives. Fig. 7 summarizes the results of these actions. During the interim incentive period, average monthly productivity increased along the log linear trend. Coincident with the tightening of the standards during the eleventh month, productivity dropped and continued to deteriorate for 5 months. The trend swings upward again, but it takes 8 months to achieve the previous levels. At the time these data were taken, productivity had suffered for over a year, during which 800 thousand tons of steel were produced.

The absence of further data and a precise definition of process capacity precludes analysis of the long-run effects of the incentive application on this particular startup. It is conceivable, however, that demoralization over the tightened standard could have resulted in a

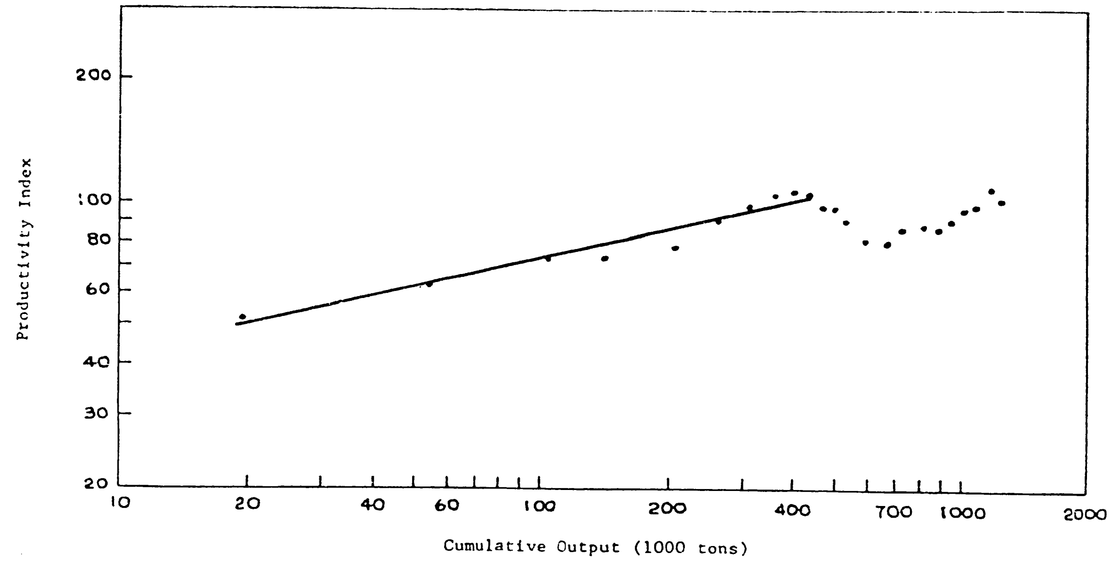

Fig. 7. Steel startup.

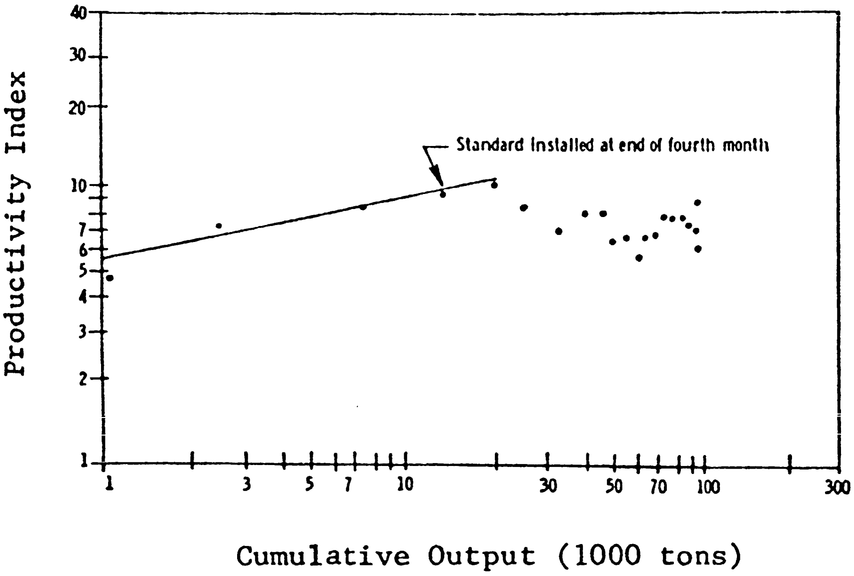

Fig. 8. Steel startup.

suboptimum *steady-state* productivity level. Since steel processes have been known to exceed their rated and/or estimated "standard" capacities, the type of interruption and erratic performance shown in Fig. 7 can leave operating managers wondering whether they have truly achieved optimum process productivity when the steady-state phase appears. Active labor resistance to pay rates can obviously heighten these concerns, but the problem is not limited to incentive applications. Startup interruptions caused by changes in production factors, withdrawal of technical support, discontinued manufacturing, etc., can also demoralize operations personnel, resulting in the same uneasiness over the optimality of steady-state productivity levels.

Fig. 8 illustrates another example of the motivational implications of incentive practices. Here the company used "past average earnings" as a means of compensating the operating crew of a new steel making process during the first 4 months of the startup. At the end of the fourth month, a permanent incentive was installed. Labor dissatisfaction with the incentive became apparent very quickly. After 1 month of experience with it, productivity dropped off and remained at approximately 70 percent of the previous level for at least 18 months (at which time these data were obtained). Again, we can not comment on the ultimate resolution of this case, but the short run consequences alone are severe enough to make management question the effectiveness of their actions. Regardless of the technical validity of the established standard, it was psychologically inappropriate —leading to demoralization and a substantial loss of productivity over a long period.

Our third example illustrates how workers bargain informally for higher earnings and the effectiveness of such tactics when there is pressure for production. Fig. 9 shows two curves: 1) an estimated startup curve made

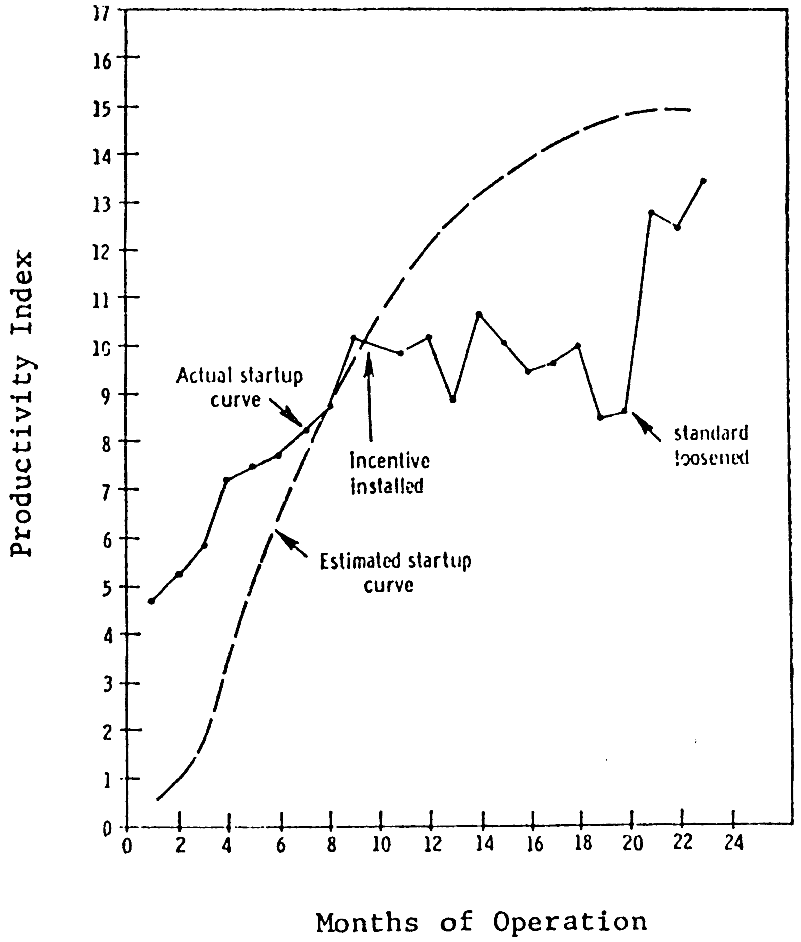

Fig. 9. Steel startup.

by the company (without reference to learning curve analysis), and 2) the actual production history of the startup. Compensation was again based upon the past average earnings in the early stage of the startup and this period was marked by steady productivity increases at a level exceeding management expectations. When the permanent incentive was installed, however, the increases ceased and productivity remained essentially constant for approximately 10 months at well below the projected level. Management needed production and consequently "bought out" the workers by loosening the standard. The immediate and significant jump in productivity that followed indicates the degree to which the operating crew was able to withhold productivity in order to bargain for a higher incentive rate.

Informal bargaining over incentives is certainly not limited to the steel industry, nor confined to startups [12]. However, when it does take place under startup conditions and management is uncertain about the true steady-state potential of a new process, the dangers are palpable. Consider a situation where workers were able to deceive or pressure management into accepting a productivity level just 10 percent lower than the true capacity of a process whose capital cost was 30 million dollars. The potential "cost" of the lost productivity over the life of the process indicates the importance of designing compensation systems that motivate workers to perform—not bargain—during a startup.

CONCLUSION

It is evident from our discussion that startups can be interrupted by a variety of factors, many of which are under direct management control, and that these interruptions can result in substantial short- and long-run losses of productivity. It follows from this general conclusion that firms should consider the components of effective startup management and develop policies that minimize unnecessary losses. A critical first step in this development is the explicit recognition that policies that are effective during steady-state operation are often inappropriate during startups.

The specific cases discussed in the paper can be used to suggest management guidelines that have some general relevance. For example, the effects of changes in product specifications, product mix, and factors of production are likely to occur in a variety of industries. Where such changes are necessary and inevitable, greater production engineering and planning may reduce their frequency and abruptness, yielding considerable gains in overall efficiency. This strategy would appear to be particularly appropriate in mechanized manufacturing; changes that can have a very dramatic impact during a startup may be postponable until steady-state conditions are reached. In many cases the primary goal is the development of maximum levels of steady-state productivity as rapidly as possible. Changes in product specification, mix, labor crews, etc., can be minimized until steady-state operating conditions have been established, allowing the operating crews to cope solely with process variables during the startup period.

The effects of discontinuous manufacturing on the startup phenomenon have implications for the broad spectrum of manufacturing industries in which lot or batch production is common. Some firms may find that extending the initial runs of a new product and incurring higher inventory charges is less costly than forfeiting the productivity losses that are associated with shorter, initial runs. In relation to the length of followon runs, there appears to be a fairly clear-cut trade-off between productivity and inventory holding charges. The data presented above showed a definite relearning phenomenon taking place after the initial run of a new product. A company facing such a situation should attempt to balance the costs of lower productivity during shorter runs against costs related to lengthening the runs (inventory and opportunity costs associated with the production of alternative products). A major step in this direction would be the development of a reliable method of estimating average productivity as a function of run length, perhaps by explicitly formulating a relearning curve function. This function could then be incorporated in an economic lot-size model. Some theoretical work along these lines has been reported, but the argument was not based on an empirically derived relearning curve [11]. Another suggestion that may merit consideration in some cases is the redesign of production lines to obtain greater product specialization and less frequent changeovers.

The importance of providing adequate technical support during a startup is a generally relevant guideline. In addition to the talents of manufacturing supervisors and industrial engineers, many startups will profit from the direct participation of development and process engineering personnel until steady-state operating practices are established. Multiplant firms that find themselves engaged in repetitive startup efforts should give some thought to utilizing the startup team concept—developing a group of experienced technical and operating personnel that can render assistance throughout the company. The size and composition of such teams can obviously be varied to suit individual requirements. The concept of a startup team appears to be particularly well suited to companies engaging in international manufacturing operations. It is well known that the startup of production facilities with indigenous personnel can be a risky enterprise. Most firms attempt to hedge this risk by permanently staffing the management ranks with Americans. This may not, however, provide as good insurance of rapid startups as the temporary involvement of highly experienced startup teams.

The motivational implications of wage incentives have widespread importance. Developing a compensation policy that will yield significant motivational pull without courting negative effects after a startup or in other parts of a production facility is a challenging management problem. The demonstrated consequences of the policies followed in the steel examples—policies that are practiced widely—indicate the need for some constructive action in this area. Some thoughts on the subject have been addressed in an earlier paper [5]. It is clear, however, that the motivational components of successful startups transcends the issue of labor compensation. Motivation of all of the individuals that take part in a startup, either directly or indirectly, is a much larger issue, one that has not been adequately explored. How should we motivate operating supervisors and technical personnel to perform efficiently during a long, trying, and frustrating startup is but one of several questions that should be answered.[3] Some reflection on the meaninglessness of traditional "standards" during startup and operating budgets and variances based upon them will indicate the complexity of the problem.

The variables that can affect startups are certainly more numerous than those examined here and their importance will obviously vary situationally. The development of a comprehensive understanding of the adaptation phenomenon and its translation into general concepts of startup management will therefore require continued study and application. A first step in this direction, we believe, would be the development of a taxonomy of "critical variables"—changes in which can disrupt a startup—for various types of manufacturing situations. These should include technical variables, which are directly related to the product and the conditions of manufacture, and motivational factors. The latter could include, for example, personnel practices, labor relations, compensation policies, informal group relationships, etc.

Explicit recognition and definition of these critical variables can alone prove very helpful by focusing management attention on potentially disruptive changes during startups. The next step will be to determine a strategy for dealing with such changes. On this point, we can only offer general hypotheses, the validity of which will have to be determined in practice. The first of these follows from earlier comments. We believe that the rapidity of a startup is inversely related to the number of new conditions with which the adaptation effort must deal, other things being equal. Hence, the number and degree of changes that are made in critical variables

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[3] Readers interested in examining a variety of behavioral concepts bearing on these issues will find [16] to be a useful starting point.

should be minimized. Secondly, we hypothesize that the durability of the adaptation phenomenon typically increases with time and experience, particularly in machine-intensive manufacture. If conditions must change during a startup, they should therefore be delayed as long as possible to diminish their effects on the momentum of the adaptive efforts. The rate of productivity increase and the degree of development of standard operating practices may serve as a rough index of the maturity of a startup and its ability to absorb changing conditions.

Our third proposition is an extension of the second to intermittent production situations. The amount of readaptation or relearning that is encountered during subsequent production runs is inversely and geometrically related to the length of the initial production run; as the length of the initial run increases, the relearning required in subsequent runs decreases rapidly. This hypothesis suggests that scheduling and/or process capacity decisions be established so as to allow significant opportunity for initial adaptation with a startup.

Reducing these propositions to practice will entail careful analysis and experimentation. Management must recognize the actions that are likely to disrupt adaptation, develop approaches to avoid them, and monitor startups for unanticipated results. These efforts will necessarily involve considerable prestartup planning and interfunctional coordination. It makes little sense, for example, to initiate a startup prior to an acrimonious labor negotiation, during a scarcity of raw material, when development engineers or skilled workers are unavailable, or if product demand is temporarily inadequate to maintain continuous operation. Startup management in this broad sense is indeed a challenging problem.

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