THE "NEW APPROACH" TO PRODUCTION

by JOHN L. BURBIDGE,

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To production historians of the future, the 20th century will be known as the "Age of Waste". An age when much of the wealth invested in production was stored away unused in the form of stock; an age when a large part of the labour force was wasted on the unproductive processing of administrative paper work; and an age in which most of the production capacity was left unused for long periods, due to our failure to control the demand cycle.

Production has reached a stage where normal evolution along traditional lines, only increases this waste. It has reached a point where substantial progress is only possible if we can find a new approach.

This Paper describes a possible approach. It advocates the use of high batch frequency line flow, for all types of product and for all levels of output. Such systems are already in use in mass production. It is here submitted that they have a universal value, irrespective of the volume, or type of product.

The Paper attempts to show that the New Approach is both theoretically sound and possible in practice. It is divided into four parts. Part I describes the material flow system, which is "production". Part II shows how material flow is related to the economies of production. Part III shows how our present philosophy of management tends to perpetuate the status quo and, finally, Part IV develops the philosophy of the "new approach", and describes how it can be, and has been applied in practice.
the material flow system

1. process sequence

The word "production" covers both the manufacture and the distribution of goods. The common feature which links both these parts of production is material flow. All production is concerned with materials, with the work done on them, with the changes in material "state" caused by this work, and with the economic effects of this "flow" of materials.

The choice of work operations and their sequence can be illustrated by a process chart. Fig. 1 is a process chart showing the sequence of operations required to produce a simple cast iron product. It illustrates the way in which the "state of materials" (their form, weight, location, and so on) is changed, and the way in which the flow of materials can be handled by a number of different companies, each carrying out one "process", or sequence of related operations.

Very few process charts are ever as simple as Fig. 1. Most of the chains of operations found in practice are cross-linked in various ways. Operations can be classified according to their effect on the material flow streams, into "dividing operations" which divide a large stream of material into a number of component streams; "combining operations" which combine a number of streams into one larger stream; and "flow operations" which leave the volume of flow unchanged. Fig. 2 now shows a number of component process charts and the way in which they are linked together by dividing and combining operations.

For any production unit, it is possible to draw a "total process chart", showing all the operations done, their sequence, and the way in which they are cross-linked. The complexity of the chart can be reduced by adopting policies of "simplification", to reduce diversity and thereby reduce the number of operation chains on the chart.

2. the flow system

The choice of operation generally prescribes or limits the choice of "work centre". Work centres are places where work is done, which are equipped with the necessary plant, tools and equipment and manned with the necessary labour to carry out certain types of operation. The general case is one in which work centres have fixed locations and materials move between these fixed centres. There are other cases where the relative motion of plant, men and materials is different, but these changes do not affect the conclusions reached.
If a map is drawn showing a production unit and the work centres contained by it, and if a Total Process Chart is then drawn on the map, with each operation shown in the position of the work centre on which it is done, the result is a "Total Flow Chart". The degree of complexity of such a chart is partly controlled by the complexity of the Process Chart, and partly by the way in which the work centres are "laid-out". For example, Fig. 3 shows diagrammatically the type of flow known as "line flow", which is obtained if the plant is laid-out roughly in the sequence shown on the Total Process Chart, and also the type of flow known as "functional flow" which is obtained if the plant is laid out in specialist groups according to function.

In most of production today, the Total Flow Chart illustrates the chance result of the independent decisions of separate specialists in product design, in process planning and in plant layout. This is not the only way and is certainly not the best way of designing a flow system. It is quite possible to direct and co-ordinate decision-making in these three fields in order to design an ideal flow system, and to do so without reducing the operational efficiency of the product.

3. the characteristics of material flow

The combined effect of product design, process planning and plant layout, is to produce a material flow system or channel system. The way in which materials are "dispatched" through this system can be varied. It can be shown that all material flow is in batches, and that this batch flow can be varied in batch quantity, batch frequency and phase.

(a) BATCH QUANTITY AND BATCH FREQUENCY

As a general case, consider the flow of components in a production unit, where the batch quantity is measured in units of the piece and each batch of material is completed at each operation before work starts on the next operation.

The output obtained equals the product of average batch quantity and batch frequency. For any given output rate there is a very large number of different batch-quantity batch-frequency combinations which can be used. For example, Fig. 4 shows a few of the possible combinations which can be used to attain an output of 1,200 pieces per annum. The limiting combination where the batch quantity is one piece is known as "line production". Generally it is only possible in a line flow channel system.

(b) OTHER CASES

The general case has been considered in which the flow is in units of the piece and all the pieces in a batch are finished at each operation before work starts on the next one. It can be shown that this idea of batch flow is a universal concept which can be used to cover all types of flow.

For example, if the materials are liquids, or gases, or aggregates of unlike particles, or long continuous filaments of wire or strip, the piece is an unsuitable unit. A change of unit does not destroy the validity of the concept of batch flow, even if the units are joined together.

Again if buffer stocks are held between operations, if the nett transfer between operations is "Q" units of material, then the batch quantity is still "Q" although the transfer is arranged. It is the same if the buffer stock is left untouched; if the finished parts at one operation go into a common pile with the buffer stock and the material for the next operation is selected at random from the pile, and again if the buffer stock forms an orderly queue.

"Close scheduling", where following operations are started before the preceding operations are complete, does affect the batch quantity. In the limiting case, if each operation were started immediately one unit of material had been completed at the preceding operation, the batch quantity would be "one".

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Fig. 4. Alternative batch quantity/batch frequency combinations to achieve a fixed output (in all these instances the output rate is 1200 p.a.)

\[\text{Fig. 5. Types of flow—differing in phase}\]
(c) PHASE

The third "parameter" controlling the characteristics of material flow is "phase". Considering the way in which batches of different components are "dispatched" through the flow system, it can be shown that there are two limiting types of "single-phase, single-cycle" and "multi-phase, multi-cycle" flow. These are illustrated in Fig. 5.

Single-phase flow is the type in which all the components required to cover a given period of time, are ordered together for completion by a common due-date. It is the type of flow associated with production control systems such as "Period Batch Control", "Standard Batch Control", "Base Stock Control" and with "Line Production".

Multi-phase flow is the type in which every component has its own special batch quantity, order date and due-date. It is the type of flow associated with "Batch Quantity Analysis" and with such production control ordering systems as "Stock Control" and "Component Batch Scheduling".

(d) STOCK

All production systems generate stock. It is impossible to have production without materials and stock is merely a measure of the amount of material in the system. There are three main causes for the generation of stock in a production unit. They are:

- lack of balance between input and output;
- protection policy; and
- the characteristics of material flow.

(i) stock due to lack of balance

At any point in the flow system, any unbalance between input and output will change the stock level. In practice the management in any single production unit should at least be able to control material flow so that this type of stock only arises at the product outlet end of the system. Its value depends on the relationship between lead time and finished product delivery time and on the variability and predictability of demand.

(ii) stock due to protection policy

At any point in the flow system buffer stocks may be held as an insurance against the possibility of a plant breakdown, a failure in supply, or an unpredictable variation in demand. The amount required to give adequate protection against an interruption in flow depends partly on the efficiency of plant maintenance, buying and processing, and partly on the characteristics of material flow, insofar as they affect the speed of material replacement.

(iii) stock due to characteristics of material flow

The characteristics of material flow — particularly batch quantity — are the most significant factors controlling the level of stock. Consider a raw material item, received into and issued from a raw material store at the constant rate of 1,200 tons per annum. If this is supplied in two batches of 600 tons per annum, the average stock will be 300 tons; if supplied in 24 batches of 50 tons, the average stock will be only 25 tons instead of 300. It is much easier to demonstrate the effect of the material flow characteristics on stock in economic terms of monetary value and this is the next matter to be examined.

the economics of material flow

1. stock value

The change in cost value of a batch of material, in relation to time, can be illustrated by means of a "stock chart". Fig. 6 shows such a chart illustrating the change in cost value of the stock during the life of a batch. The height of the plateau on which the chart is drawn represents the buffer stock and the remainder of the chart shows the stock induced by the characteristics of material flow.

It is assumed that the batch quantity in which the material is received from the supplier is the same as that used in processing. This simplifies the "model" for exposition, without damaging its universal validity. By using total cost (actual cost) for valuation, the stock value can be made the same as the "investment".

Fig. 6. Stock chart for a single batch
If a number of batch charts is arranged in a series to represent the continuous output of a given component, it will be found that the average stock is a function of the batch quantity, the batch frequency and the shapes of the batch charts. These relationships are illustrated in Fig. 7. It will also be observed, that the same factors of batch quantity, frequency and shape, control the amplitude of variation about the average. High batch frequency systems, have stock cycles with lower amplitude than those with high batch quantity and low batch frequency. Batch charts with a low ratio of throughputs time to consumption time (typical of distribution), produce higher amplitude stock cycles than those with a high ratio. Diagram “E” in Fig. 7 shows the effect of lack of balance between input and output, on the stock. Balanced flow occurs when the consumption periods for succeeding batches end and finish at the same moment.

If the stock curves for all the different components using a flow system are now combined to find the total stock generated by a given flow rate, it will be found that the characteristics of variation are governed partly by the amplitude, frequency and symmetry of the component stock curves, and partly by the phase relationship. Fig. 8 shows the effect of phase on Total Stock. Multi-phase systems tend to generate unpredictable and erratic variations in Total Stock, due to the drifting in and out of phase of the peaks and troughs of the component stock curves. They also tend to generate higher stocks than single-phase systems. This is partly because they cause obsolescence and lack of “set” Balance in the Stock, and partly because single-phase flow can be controlled at much higher batch frequencies.

The types of variation described above occur even at constant output rate. If batch quantity and/or batch frequency, are now allowed to vary to match a fluctuating demand cycle, the stock variation will be still further exaggerated as shown in Fig. 9.

This type of “model” can be used to represent the stock variation in any type of production, whether concerned with manufacture or distribution. It is possible with a computer to simulate the effects of different types of change and thus test their effect on the stock and investment in production.

2. capital tie-up

Batch charts can also be used to show the changes in capital tie-up imposed by individual batches,
reflecting the flow of money in the business rather than the changes in value of the physical stock. Fig. 10 shows a capital tie-up chart and illustrates the effect of credit. These charts can be used in exactly the same way as stock charts, to simulate the effects of different types of material flow on the capital of a company.

3. Cost

The shapes of the batch charts are defined by the batch values for cost, throughput time and consumption time. It is now necessary to consider the link between the values selected for types of flow system, batch quantity, frequency and phase, and the induced changes in the batch charts. In a complex system of thousands of inter-related variables such as production, it is impossible to deduce exact quantitative relationships to link individual changes in the parameters of material flow with money flow. Such attempts must be pseudo-scientific because the sub-systems cannot be isolated and tested. There is, however, a wealth of practical experience, or evidence, from which it is possible to "induce" the principles governing the direction of change in the economic variables (cost, investment, return, profit and so on), which will be caused by a given direction of change in parameter value. Here only direction of change will be considered.

Three of the principal factors which affect cost are design, process planning and plant layout. These are the same factors which control the type of flow

Fig. 8. Effect of phase on total stock cycle

Fig. 9. Effect of demand cycle on normal stock cycle

Fig. 10. A batch capital tie-up chart
Fig 11. "Direct" changes in cost due to changes in flow parameter

system. It is a common experience in production that improvements — or in other words a reduction in complexity — of the flow system, tend to reduce total costs. There are obvious reasons for this reduction in the lower costs of handling, administration and storage, which arise as a result of better flow. It can be "induced" from experience that those decisions in design, production planning and plant layout, which tend to contribute to an improvement in the flow system, will also contribute to a reduction in Total Cost. It may be that decisions which promote good flow will increase direct labour cost, or other components of total cost in particular instances; it is submitted, however, that the best decisions inside the limitations imposed by good flow, will tend to promote lower total costs than the best decisions without this limitation.

Considering now the changes in batch cost caused by changes in the parameters of batch quantity, frequency and phase, it is necessary to recognise

Fig. 12. "Direct" changes in cost due to batch quantity change at constant output rate
that there are two principal types of change: "direct change" and "potential change". Direct changes are those induced automatically by the relationship between the variables in the existing system. Potential changes are those which are made possible by parameter change, but can only be realised by executive action which changes the system. The savings due to "potential" change are those which are lost due to Parkinson's Law, unless direct action is taken to achieve the potential. The "direct" changes in Total Cost with changes in batch quantity, batch frequency, their product output, and phase, are illustrated in Fig. 11. In all cases there is a large element of fixed cost and a smaller element of variable cost. The elements of Total Cost which are variable, are, however, different in each case. Because the batch quantity and batch frequency scales are closely related, it is possible to show the effect of combined change at constant output rate on one chart, as in Fig. 12. That the flat shape of this curve is typical can be tested by analysis of company trading accounts, analysing the effects of changes in batch quantity and batch frequency on each of the large number of different cost items, using the same technique as is used in the preparation of a break-even chart. It is submitted that changes in batch quantity at constant output rate, generally have an insignificant "direct" effect on total cost, over most of the possible range of batch quantities.

The reduction in cost due to change of phase is partly due to the simplification of control and partly to the reduction in obsolescence, when single-phase flow is employed.

The "potential" changes in cost due to changes in batch quantity, frequency and phase are best illustrated by an example. Fig. 13 shows the administrative paperwork required to order and control the production of one batch of one component, in a

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Fig. 13 Paperwork required for one batch of one component, with low frequency, multi-phase flow and functional layout
machine shop where the plant is laid out on a functional basis and a multi-phase ordering system is used. Because there is no fixed route for all material flow and because all components have different start-dates and due-dates, all this paper is necessary. It is possible in a line flow system using single phase ordering, to control the whole flow of all components with only one or two copies of a single "list order" each period. The potential saving in indirect labour and expense is enormous. Generally, in the present state of industry and commerce, the "potential" changes in cost due to changes in flow parameter are more significant than the direct changes. The cost of administration and control is very much less with line production than with any other type of flow.

There is a close relationship between phase and batch quantity. In the limit when all batch quantities are "one", single-phase flow is the automatic result. Each reduction in batch quantity reduces the degree of out-of-phase. Considering both the "direct" and the "potential" changes in cost induced by a change in batch quantity, it can be stated as a principle that: the "total" effect of reducing batch quantities at constant output rate, is to reduce total cost.

4. throughput time and consumption time

The throughput time for a batch can be divided into components of "waiting time", "setting time" and "operation time". "Waiting time" is a function of flow type, of load, of batch quantity and frequency and of production method. "Setting time" is mainly a function of plant and tooling design, but is also affected by loading sequence and batch quantity. "Operation time" is a function of method, operating efficiency and batch quantity. Batch throughput time — the sum of these highly variable components — has a certain fixed element which does not vary with batch quantity, but the total value tends to fall with each improvement in flow and with each reduction in batch quantity.

Consumption time on the other hand is mainly a function of demand.

5. output and capacity

The output at any point in a flow stream can be represented as a series of pulses indicating the completion of batches in relation to time. The length of the pulses can be made proportional to the values of the batches. The output can also be represented by a curve showing the total value of all the pulses occurring in successive periods of time. The type of cycle achieved is again a function of batch quantity, frequency and phase.

Output is limited partly by capacity and partly by demand. Capacity is a measure of the maximum output which can be achieved. It is limited by the amounts of material, labour, plant and capital available, by the balance between these factors, by methods, and by the efficiency with which they are used. In practice, due to the interdependence of different parts of the system, capacity at any given moment is usually limited by one bottleneck or restriction, which limits throughput at one particular point in the flow stream.

Fig. 14 now illustrates the effects on output of the capacity limit and of variations in demand. Only a part of the potential capacity of labour, plant and capital is profitably used under present conditions.

6. demand

Demand can again be represented by a series of pulses representing orders received, or again by a curve representing the total values of these orders in a series of given time intervals.

Demand at the final or consumer end of the flow stream can be affected by many factors such as the weather, the seasons, special holidays and so on. This type of variation can be called the "natural demand variation".

If the natural demand is predictable and can be forecast, it should be possible to meet it, as shown in Fig. 15, by matching the demand variation with an equivalent output variation; by keeping output steady and using stock to absorb the demand variation; or by a compromise in which part of the
demand variation is absorbed by stock and part by output variation. In other words it should be possible to work with a lower manufacturing output variation than the natural demand variation, and gain the advantages of maximum use of capacity and an even level of employment.

In practice this condition is very seldom achieved. The typical condition is one in which the natural demand variation is considerably magnified by the time it reaches the manufacturing unit. It is submitted that this magnification is mainly due to the wide use of "stock control" and to the low processing batch frequencies and low demand order frequencies, used with that system of ordering.

Most production flow today is controlled by "stock control". The material flow streams are broken into segments by inventories both at company boundaries and very often inside individual companies. Orders are released according to the stock level at each inventory. This type of system always magnifies the demand variation, so that a ±10% natural variation in demand amplitude, after transmission through three inventories (say retailer, distributor and factory stock) can easily be increased into ±40% variation in the demand on the manufacturing unit. The effect is known from frequent observation, and research on "Industrial Dynamics" at the Massachusetts Institute of Technology has shown that it is the natural behaviour of this type of system.

It is submitted that the reasons for this magnification are as illustrated in Fig. 16. The demand cycle transmitted by each unit tends to vary inversely with its stock cycle. The natural stock variation in each unit is increased by the demand variation it receives (see Fig. 9). Each unit tends, therefore, to transmit a higher demand variation than it receives.

The condition for minimum magnification of the demand cycle is one in which both processing batch frequency and demand order frequency are at a maximum in all units in the flow stream.

Magnification must be significant with a stock control system, because such systems have multi-phase flow, and can only be operated at low batch frequency. At high batch frequency, the batch "lead time" tends to exceed the "throughput time" making it impossible to set an "order point" or "re-order level". Stock control systems, therefore, induce the conditions which give maximum magnification of the natural demand cycle.

It should be noted that the demand and stock cycles in industry are never as regular as those shown in Figs. 15 and 16, and the demand cycles never mirror the stock cycles in relation either to shape or time, in the precise manner illustrated. These diagrams merely illustrate the mechanism of change.

7. The trade cycle

It has been demonstrated that the cylindrical changes in demand at company level are a function of the natural demand cycle, of the type of ordering system, and of the batch quantity, frequency and phase used in both processing and ordering. It is a logical extension of the same principles, to say that the probable cause of national and world trade cycles is the cylindrical nature of the demand curves in the component flow streams.

Because the cycles of demand generated by most companies today have high amplitude and differ in frequency and phase, it is inevitable that there will be national and world trade cycles, and that there cannot help but be occasions when the peaks or troughs of the component cycles drift into phase causing "boom" or "slump".

Although there are many other factors which affect the trade cycles, they only modify the inevitable cycles produced by low batch frequency flow. It is submitted that the amplitude of the trade cycle could be substantially reduced if we reduced the amplitude of the demand cycles at company level, by increasing the processing batch frequencies and demand order frequencies used in production.

It is not surprising that present efforts to control the trade cycle by changes in monetary policy and taxation are unsuccessful. This is inevitable because, apart from a tendency to increase the amplitude of the natural demand variation, such methods are mainly directed at treatment of the symptoms and leave the disease untreated.
8. Predictability and flexibility

It should be noted that the predictability of future demand is a function of the characteristics of demand variation. In the limit, if there is no variation, demand is completely predictable. If there is a variation but it is completely regular following some fixed natural cycle such as the seasons of the year, then again it is comparatively simple to predict future demand. Under present conditions most production units must always suffer an erratic variation in demand and the accuracy of forecasting or prediction depends mainly on the time ahead which has to be covered.

The "flexibility" of a material flow system, or its ability to follow demand fluctuation, again depends on the batch quantity, frequency and phase. Fig. 17 shows, for example, that if the batch frequency is two batches per annum, the company must have an average notice of seven months of any change in demand, if they are to change the production programme without losses due to obsolescence or increased capital tie-up. An increase in batch frequency to 12 batches per annum reduces this period of notice to an average of one month.

In industry today, we expect miracles of detailed prediction from our Sales Managers. These are both impossible and unnecessary. Companies which operate at high batch frequency require only short-term "firm" programmes, and can change plans quickly without obsolescence and without large changes in capital tie-up. In the limit, with line production, and with simple products with short lead times, it is often possible to reduce the firm programme to one or two days, and to load only firm sales orders on production. The crystal ball can then be thrown away.

The present approach

It has now been demonstrated that the adoption of single-phase, high batch frequency line flow can reduce stock and capital tie-up; release factory floor area; reduce data processing; reduce total cost;
simplify and increase the flexibility of control; and, finally, by smoothing the demand variation, can increase effective capacity and output.

The most striking characteristics of production today are high capital tie-up, highly variable demand cycles, low batch frequency material flow, and paper-ridden, bureaucratic inflexible controls. It remains to consider why the obvious solution of line production is so seldom used outside the limited field of mass production.

The reasons can be found in certain deep-seated beliefs, which form part of our present philosophy of management. Here five of these beliefs will be briefly considered.

1. The belief that a reduction in direct labour cost reduces overheads in proportion to the allocation rate

This is a belief never held by the trained accountant, but still fairly widely held in other branches of management.

Consider a company which uses an allocation rate of 200%, on direct labour to absorb its overheads and find Total Costs. Assume that a particular job has a material cost of 15s. 0d., a labour cost of 10s. 0d., overheads of £1 (200% of 10s. 0d.), and a total cost, therefore, of £2 5s. 0d. If the labour cost is now reduced to 5s. 0d., the new total cost will be £1 0s. 0d., with an apparent saving of 15s. 0d. The actual saving, providing there is no change in output, will be little more than 5s. 0d.

The reason is obvious. The apparent saving of 15s. 0d. merely exploits the approximations used for convenience in costing. There is very little real change in overheads directly induced by a change in direct labour cost.

The importance of this belief is that it misdirects nearly all the effort for cost reduction in industry towards direct labour cost, and seems to imply that it is unnecessary to worry about overheads because they will fall automatically if direct costs are reduced. It also precludes the consideration of changes which increase direct costs, but reduce Total Cost due to their effect on overheads.

2. The belief in stock control

This belief holds that a satisfactory material flow can be generated by dividing a given flow stream into segments separated by inventories. Flow is then maintained by releasing orders on the basis of a re-order rule founded on stock levels.

As explained earlier, this type of system inevitably exaggerates the demand variation, so that a small demand variation at the final outlet will quite commonly be multiplied eight times or more after the third or fourth inventory. The system has the serious deficiency that it can only be operated with large batch quantities and small batch frequencies, thus reducing flexibility and further inflating the cyclical variation.

3. Belief in the so-called economic batch quantity theorem

This theorem holds that there is a large and significant variation of cost with changes in batch quantity, and that for each component produced there is one special batch quantity which will give minimum cost. The case against this theorem has been developed at length in previous Papers; the following summary gives eight of the reasons why it is false:

1. By imposing different batch quantities for different components, it itself imposes multi-phase flow, with its associated high costs of obsolescence, storage and administration. A substantial reduction in costs can be made by
changing to single-phase flow. Batch quantity analysis can only find minimum cost in the inefficient system imposed by itself. It can’t find minimum possible cost.

2. The belief that cost varies substantially with batch quantity change can easily be disproved by detailed analysis of company trading accounts. Such analysis normally produces a comparatively flat curve over most of the possible range of batch quantities. If the total change is insignificant, there must be something wrong with the deduced mathematical models, which show a significant variation for components.

3. The economic batch quantity always gives a sub-optimum return on the capital investment. Due to the shape of the curve, it must be possible to find a batch quantity lower than the E.B.Q., which will give a higher return on the investment. By the same reasoning, if the economic (sic) batch quantity is used throughout, a large part of the stock must represent an investment at a low marginal rate of return, which could easily be bettered by re-investment.

4. It represents a ridiculous and improvident investment policy. It fixes the amount of capital to be invested in stock by a very large number of separate calculations, which produce a chance total without any reference to the actual amount of capital available.

5. Many of the factors which have to be used in the “models”, cannot be measured economically or are intangibles with no exact meaning which have to be guessed (e.g., storage cost per piece, and opportunity cost).

6. It treats method as a constant; it measures, for example, the cost of setting-up and uses this value as a constant in the model. It ignores the—in practice—much more profitable possibility, that an investment in method and tool development instead of in stock could reduce setting-up cost and overheads generally.

7. In large scale high volume production (both manufacture and distribution), line flow and maximisation of the rate of stock turnover are accepted and successful strategies. In low volume mixed production, the strategy of batch quantity analysis at present holds favour. In a system with such an obvious unity as production it is unlikely that two diametrically opposite philosophies can both be right.

8. In the extremely complicated system of interrelated variables which is production, it is unlikely that any simple solvable mathematical equation, created by deduction from basic premises, can form a “model” which is isomorphous with the system. Even the most complicated expression can only hope to give a rough approximation of the relationships at one moment in time, and to have the most transient of values.

4. belief in control by a number of independent specialists

In most of production today the control function is divided among a number of independent specialists, with a traditional division among them of the responsibility for parameter changes. Generally, the specialists alter these parameter values with a view only to their own special areas of control. Because any parameter change tends to affect all the output variables, such an arrangement only complicates the system and reduces its stability.

A simile might be a car, so designed that one man operated the steering wheel, another the accelerator, another the clutch, another the gear lever, and so on.

Success in control depends on choosing a combination of parameter values which will influence all or most of the output variables to change in the required direction. Integration is essential for efficient control, as every parameter change must be considered in relation to its effect on all output variables. The present system not only reduces stability; it also tends to duplicate records and other administrative paperwork, and it thus seriously inflates overheads.

5. belief that line layout cannot be used for low outputs

It is generally believed that “line layout” is only possible for mass production. This is a type of rotating fallacy which often occurs in highly departmentalised bureaucratic organisations.

The production engineer knows that line layout is almost always technically feasible, but believes that there is an economic bar—the economic batch quantity theorem—to its use at low output rates. The non-technical, financial manager probably knows that the economic limitations are extremely suspect, but believes that there is some technological limitation to the use of line layout.

Between the two of them it is seldom even considered.

the new approach

1. the aims and general approach

The primary aims of the New Approach are: to reduce stocks and thus release capital and floor space for more profitable use; to simplify administration and control, thus reducing cost and releasing indirect labour for more productive and creative work; and to increase effective capacity and output, by reducing the amplitude of the demand cycle.

The principal methods advocated in order to attain these aims are: first, the creation of line flow systems; second, the use in these systems of high batch frequency single-phase material flow; third, the substitution of high demand frequency flow control for stock control; and, fourth, the simplification of administration and control procedures.

2. creating the line flow system

Consider, as an example, the complicated and difficult case of a general engineering works making a wide range of engineering products in small volume, by such processes as forging, casting, machining, press work and assembly.
It is possible to classify all the components made in such a factory into "families," so that all the components in each family are made by similar operations, in the same sequence, on the same plant. Classification can be greatly simplified by: reducing material and component variety (simplification); by some redesign to make awkward components fit the classification; by adjusting existing process layouts to obtain standard process sequence; and by adjusting the make-or-buy distribution, to lose awkward components and bring back bought items which will fit into "families."

This process does not represent an attempt to force a square peg into a round hole. It merely reflects the natural order of things. Components normally do fall roughly into "families,” which can be processed by the same items of plant, and the sequence of operations does normally follow roughly the same pattern for all items in a family.

3. plant layout

For line flow, the plant must be laid out in the sequence dictated by the standard process layout for each "family."

One of the problems is to achieve an approximate balance between the capacity supplied for each operation. This can be achieved by way of the tested methods already in use in mass production; by, for example, supplying more machines for long operations than for short ones; by doubling the lines so that one operator can do two or three of the short operations; or by changing methods and re-designing tooling to eliminate bottlenecks.

An excuse often made for not using line flow with low volume output, is that it is very difficult to obtain an exact balance of plant capacity. This is true. It is also true, however, that such a balance is even more impossible with functional flow. The capacity of the line flow system in practice, is generally higher than that of the equivalent functional flow system.

Lack of potential output balance is always accepted on automation lines. Actual balance is only obtained by de-rating most of the machines in the line. For some reason the same solution is seldom accepted for manned lines, although it is generally possible to obtain approximate labour balance. It is generally forgotten that de-rating can itself pay dividends—for example, improved quality, and reduced maintenance.

4. tooling

Each machine must now be equipped with jigs and tools, so that all the components in the family can be processed. Because all the components in each family are similar in form, it is usually possible to design adjustable tooling which can be used for a number of different items. For this reason the amount of tooling and the tooling cost are generally less with the line flow system, than with normal batch production and a functional layout.

5. setting-up

It will be realised that if the machines in these lines can be reset in a matter of seconds, rather than in hours and minutes as at present, there is nothing to prevent their use at high batch frequency. If setting time is short enough, there is no reason why the lines should not be reset 20 or 30 times a day for different components. The lines can even be scheduled to make "today's", the parts required for "tomorrow's" assembly, and be reset again the next day to make the following day's exact assembly requirement of the same parts.

It is surprisingly easy to reduce setting times. The problem is one which has received little attention. Because the engineering industry normally uses large batch quantities and setting-up cost is therefore only a small part of cost per piece, it has not seemed worth the effort to reduce it. If the effort is made, setting-up time can generally be decimated at comparatively small cost.

The leading authority in this field is an Italian engineer, Signor Patrignani, who has achieved spectacular reductions in the setting times for machining and sheet metal working processes. As an example, it is possible with his equipment to change the set-up on a 90-ton power press in 15 seconds, compared with the 30-40 minutes common in the industry. It is no criticism of Signor Patrignani to say that his solution is very simple. He has merely designed a simple method for the rapid and automatic location of die-sets on presses. His real genius lies in his recognition of the problem. Once the need is realised, the solution is generally a comparatively simple exercise in tool design.

6. a practical case

The instance of a general engineering works making a wide variety of products in small volume was chosen because it is one which is already being successfully applied.

A French manufacturer of special switchgear for the electrical industry—Messes. Alsthom-Lecourbe, Paris—have converted part of their plant to this system, using a similar approach to that described above. The results achieved have included a very big reduction in stock, three to four times the output from the same floor area, a reduction in lead time for new orders from three months to three weeks, a 45% reduction in throughput time per order, and reduced tooling costs.

An additional and unexpected advantage was an improvement in morale. In a Paper delivered to the Xe Congres Internationale d'Organisation Scientifique, Paris, 1957, M. Mongon—a director of the Company—attributed this improvement to the operator's closer association with products, rather than with isolated operations.

It will be obvious that this type of manufacturing represents one of the most difficult cases which could have been chosen for the introduction of line production. The fact that it is possible makes it likely that even better results could be obtained in other less complex industries.

7. automation

The limit to the use of automation is the feasibility of line production. If small quantity mixed product output can be handled by line production, then auto-
The organisation of flow control systems of this type would be comparatively simple inside the vertically organised industry. It would call for co-operative effort in many industries where the organisation is horizontal.

10. the application of the new approach

The final solution of “line production” has been described. The New Approach is not, however, a one-step philosophy. Many of its advantages can be obtained very quickly by a progressive application of the principles. For example, the progressive completion of the following programme might well make the whole programme self-financing, the changes being financed from the progressive reduction in capital tie-up:

1. reduce batch quantities immediately to the limit which can be controlled with existing systems;
2. classify the components into “families”;
3. analyse the components by output value and select the 8% to 12% of components which represent the majority of the total output value (in engineering 12% of the components will often account for 75% or more of the total output value);
4. segregate the plant for the “families” which contain the majority of the high output value components into groups (group layout);
5. adopt a simple single-phase ordering system (Period Batch or Standard Batch control) for these groups, and increase purchasing and processing batch frequency to a minimum of 12 or 13 batches per annum;
6. study the process sequence in each group, study the setting problem, and design one or more “lines” to handle all the components in each family by line production;
7. repeat the process for the remaining “families”, of lower output value;
8. take the savings possible by eliminating the production flow stores previously required due to multi-phase flow;
9. Simplify data processing and integrate control. Eliminate the costly complicated systems necessary to control low batch frequency, multi-phase flow. Substitute the simpler integrated low cost systems appropriate to line production;
10. tackle the demand problem, adopting flow control systems in place of Stock Control;
11. tackle the supply problem, persuading suppliers to give high batch frequency supply;
12. adopt automation both for material processing and for data processing with the computer.

conclusion

Our present methods of controlling material flow result in an enormous waste of capital, indirect labour, and production floor area. Only a small

(continued on page 793)
The tips and shanks are then rumbled or shot blasted to remove any grease or scale which could cause a poor contact between the tool and the electrode during welding. The tools are flash butt welded and placed in a gas furnace at 900° to 1,000°C. for stress relieving. They are allowed to get a thorough soaking at this temperature before being raked into bins to cool. Certain tools whose shape makes them susceptible to cracking are given a full annealing as an extra precaution; this also leaves the tools in a softer condition for rough grinding.

Turning and planing tools are either rough ground by “off hand” methods using templates, or on oscillating grinding machines set to give the desired rakes and clearances. The tools are then hardened, usually in salt, tempered around 570° to 580°C. to give a Rockwell C reading of 63-65 and then blow-tested. The blow-test consists of giving each tool a sharp uniform blow on an anvil to ensure that it is thoroughly sound. The tools are then shot blasted, finish ground and marked. A crack detecting operation is carried out to show up any defects on the exterior of the tool, and after a further inspection for shape and dimension, the tools are ready for despatch.

Conclusion
As will be realised from the foregoing, the soundness of the tool depends upon the soundness of the weld. Therefore, correct welding procedure is of major importance in the production of high speed steel tools. Experimentation is usually the quickest and most reliable way to establish production data, and decide on machine settings.

The fully automatic flash butt welding machine is now regarded as a precision machine tool in every respect and it is consistent and fast in operation. It is ideal for a mass production of welded tool and drill blanks, as well as for small quantities, and special tools.

The uses of flash butt welding are many, and this Paper attempts to cover only one small application.

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**THE NEW APPROACH TO PRODUCTION — concluded from page 784**

part of these production factors is at present applied to useful productive work.

The New Approach is a philosophy for those who believe that this waste is unnecessary and that in line production and its derivative, automation, there is the possibility of an immediate and explosive leap forward in output and in world living standards.

**bibliography**

7. BESIERE, M. P. (No date) “Pent-on envisager l’application de moyens nouveaux pour abaisser les prix de revient dans les fabrication mécaniques?” Societé des Ingenieurs d’Automobile, 6e section technique, 59.

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