SYSTEM DYNAMIC ANALYSIS AS A FIRST STEP TO IMPLEMENT FLEXIBLE OPERATION OF MANUFACTURING

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Changing and improving manufacturing operations in such a way that optimum flexiblility is achieved is a standard task nowadays.

Enhanced by the availability of CIM concepts and techniques the pervading paradigm how to solve the problem tends to be based on the structure of the data processing systems.

Since management of data systems and inventory are often handled as different functional entities the complex relations of the effects of goods flows and data flows that make up the dynamic behavior of the operations as a whole often evade appropriate treatment.

CIM related practice, doing the easy things first, is to follow a hands-on bottom-up approach in optimising first individual process steps using preferably discrete simulations and then trying to add those optimised islands to a system.

If we follow the original ideas of J. Forrester and his group a quite different approach is proposed. In a combination of top-down analysis and bottom-up implementation we would first apply S.D.A. with continous simulation to understand the operations in their context as is. After optimisation we would implement the upgraded system bottom-up.

The approach uses two levels of imaging the real system to a model. Top level simulation with a continous model is used to analyse and define dynamic behavior, feed back loops and embedding of operations in the context of sales and supply.

Bottom level simulation thereafter serves to check detailed implementation of single tasks within the dynamic specifications arrived at by the continuous overlay model.

The procedure allows to exploit the strong points of both continuous and discrete simulation, namely analysis of the dynamic behavior of complex and intertwined systems of flows of goods and data on the one hand and detailed analysis of process steps involving clearly defined operations with workpieces handled.

A few examples serve as illustaration how this first step of a top-down optimising with the aid of S.D.A. worked in defining manufacturing systems as a whole before starting bottom-up implementation.

As the S.D.A. model is a lumped together model of the real system, its use for on-line prognosis can be a welcome by-product.

Introduction

In this paper we will first report two actual applications showing their respective process configurations and problems.

With this background we will then summarize the findings so far, including modern production planning systems and their image in continuous simulations.

An example of different production control systems, namely either capacity-control or volume-control, is then explained.

The advent of computer-aided MRP (Manufacturing requirement planning) with strong task scheduling capabilities has very much changed focus and context of application of continuous simulation for problems of industrial dynamics. If restricted to the very important top-down problems of system design and setting the context for local policies encouraging results complementing
the use of the powerful scheduling capabilities of actual MRP were obtained.

Two typical assignement cases

In the two cases reported, the tasks were:

- establishing actual procedures of the system in place by imaging into a simulation model
- analyzing the key problems and possibilities for improvement.

Case A

The problem was how to establish the operational system for a production which would be controlled by pull-operation of the final assembly. As a condition it was stated, that the capacity on this final assembly should be used within +/- 5 % of variations. Order volume would arrive with +/- 30 % on a weekly basis. Accepted delivery delay of the market was 4 months and as is the sum of normal leadtimes was somewhere exceeding 5 months.

In a first phase, in order to establish a simulation model it was realized, that one had to arrive at a clear definition of process steps and process lines of chained process steps.

Since obviously the whole process from orders coming in to final assembly had to be included, after a few hesitations sales and engineering found themselves pictured into the model also.

The result of this first phase is represented in its final version in Fig. 1 showing four different process lines to the commissioning stocks before assembly:

- external parts supply
- standard parts
- order specific subassemblies
- order specific electronics, switches and cables

The next phase served to verify how the system worked. Within the old system there was used a mixed push-pull system controlled by direct interaction of shop-floor managers. As verified by the model according to Fig. 2 its proper function was very easely disturbed.

On the basis of this first analysis the problem to reach delivery delays within market tolerance as illustrated by Fig. 3 [2] was identified as follows:

- in order to reduce the volume fluctuations from +/- 30 % per week at order input to +/- 5 % at final assembly, one would have to use an order backlog before entering a MRP of something over 1 or 2 months.

  A structure wich is very much generalized that would help to understand the smoothing function of a backlog before entering any MRP resulting in a "Master Production Schedule" is Fig. 4 taken from [1].

- by further working on the process lines identified the maximum sum of leadtimes had to be reduced from over 5 months to roughly 2.5 months since from an acceptable delivery delay of 4 months 1.5 months are needed to generate the smoothing backlog.

<u>Case B</u>

In the B case, a modern MRP II was installed since years. Production was organized along stable parts-trees as the process lines and as input to the MRP a projected one-year backlog was used.

The company had over the years concentrated on the final assembly as its main added value and by introducing JIT-like measures stocks were reduced everywhere in the process.

As competitive markets increased demand fluctuations and suppliers in addition did not always keep their delivery schedules, problems of inadequate supply and capacity usage developped.

As a basis to identify not only local measures to improve operational flexibility, but also to assess the impact of changes in the planning policy a continous simulation model, part of which is illustrated in Fig. 5 is established as a quasi permanently updated model for this purpose.

The main need to establish a separate model for continuous simulation was, that using the MRP itself for generating different what-if schedules would not cover the need to analyse policies on local and top-down levels.

General structures

Summarizing what has been learned with cases like the ones illustrated we can roughly define three categories of production systems.

The parameters used to differentiate would be:

- delivery delay flexibility
- capacity usage
- cost flexibility

With this we find the categories to be

Chaotic single order process:

characterised by a process routing that is different for every single order. An operation of this kind usually follows fixed deadlines and capacities and plays with cost flexibility.

Such operations are simulated on local level by discrete simulation, even mostly with the MRP in place itself. [3]

The top-down context, including questions of necessary backlog size are the only problems amenable to continous simulation.

Flexible production lines

These are characterized by one or more stable process chains with common ressources. Operations tend to follow fixed deadlines and cost, playing with capacity usage. Depending on complexity we find MRP implementations treating the set-up as chaotic single order process or emphasizing the set of stable process chains.

Faced with stringent needs of flexibility it is usually good advice to prefer the second approach. This incidentally makes mandatory the use of a continous simulation model for local policy ananlysis also.

Mass production lines

In this kind of operation, use of several single process chains in parallel is made, e.g. as case B illustrated above.

The aim is to produce with fixed cost and capacity limits and use flexible delivery delays with stock management.

For cases like these, full simulation support by continuous simulation, often including the MRP is appropriate.

Illustration of a simple control-policy experiment

Among the several cases analysed so far, two different control-policies using a MRP for stable process-lines were encountered.

These are using the MRP to control capacity usage, see the JIT-Kanban system treated by O'Callaghan [1] and/or the more standard control of volume based on a planning schedule such as MRP II.

The model to investigate the difference of the two approaches is represented in Fig. 6. It shows one of the assembly lines of case B mentioned above which are controlled by a MRP II type system. The basic structure is again made from building blocks such as explained e.g. by [1].

In the experiment we wanted to know if the size of the frozen schedule period PPT had an influence and what would be the general convergence of the control policy in question if the system was subject to demand variations.

The only parameters varied are:

- the frozen period PPT
- rate/capacity algorithm or volume algarithm

Results of rate-controled model:

Fig. 7/8 for PPT=10 demonstrate that if this period is big enough, the control policy does not work any longer.

As borne out by comparison to Fig. 9/10 a rate-control is functional only if PPT is small enough compared to the process leadtimes.

(Individual leadtimes are 1 unit, total process leadtime is 11.5 units in the model)

Results of volume-controled model:

volume control was implemented by applying appropriate timewise shift to the Master-Schedule signals for the individual process steps.

In Fig. 11 the method used is illustrated. NPP is the input from the MRP, causing spipments SR calculated and applied to the models output delayed by the total process leadtime SRD.

OUT (1) and OUT (10) represent the MRP-signal for first and tenth process stage respectively.

In Fig. 12/13 we see the result of a simulation using PPT=10, which with rate-control resulted in totally unacceptable behavior.

If we now compare Fig. 14, where we used PPT=2 for volume - control, there is no difference in the very straight convergence behavior. The small circle visible in vicinity of equilibrium is caused by the rate-controled options-tree, see model structure Fig. 6.

This superior behavior of a volume-control system is of course the backbone of the MRP II approach, although in practice limited by capacities available.

Conclusions

Even amidst very powerful MRP with sophisticated scheduling capacities there are quite a few very important issues in production system planning, design and operation that can be very effectively adressed by continous simulation.

Among the main areas, where analysis and problem solution is speeded up by such simulation support are:

- top-down optimizing of logistic structures setting targets and context parameters for:
  - automations systems
  - MRP systems
  - backlog policies
- analysis of local policies in process lines within top-down system context for:
  - scheduling blocks (including discrete simulation models)
  - automated process islands
- forecasting behavior of system, e.g. in response to:
  - contingency planning needs
  - change and adoption of control-policy

One remark about software and hardware used. We found, that PD and PD+ are sufficient for most first exploratory investigations.

Getting more on the side of permanently installed "Production Flight-Simulators" however has made us look into models in the range of just below some 10 to 20 kilo-equations.

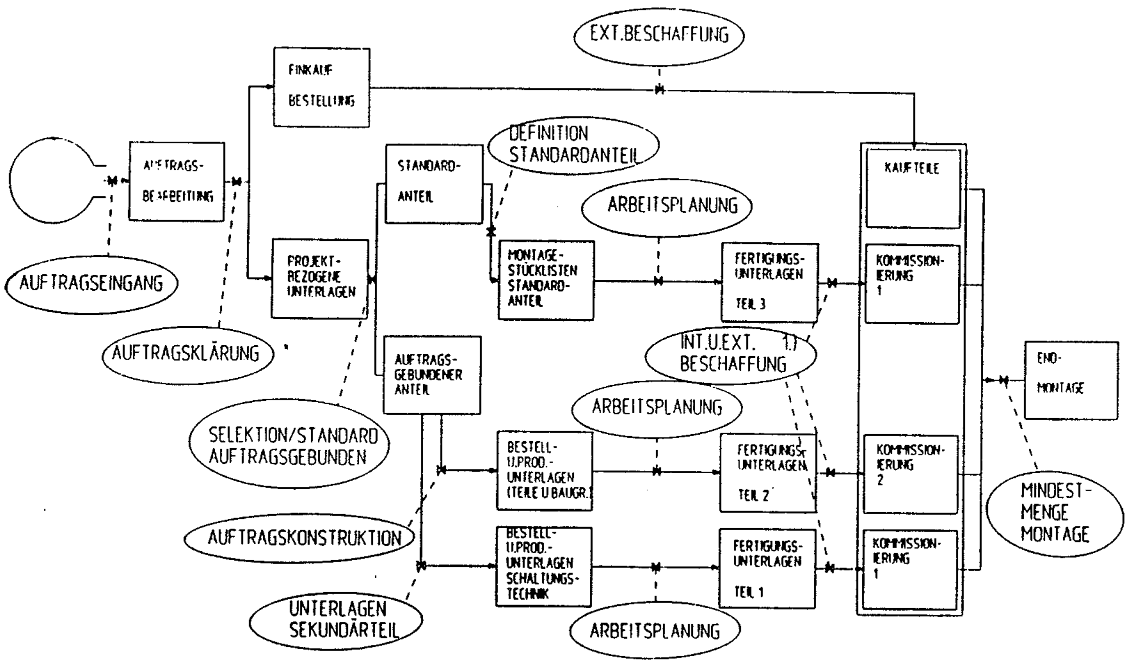
Such a size however is still very much smaller than what discrete simulations would take or what is implemented in the MRP software actually controlling the real systems we are simulating.

References

[1] R. O'Callaghan, A System Dynamic Perspective on JIT-Kanaban 1986 Int. Cauf. S.D. S. Sevilla, pp. 959-1004

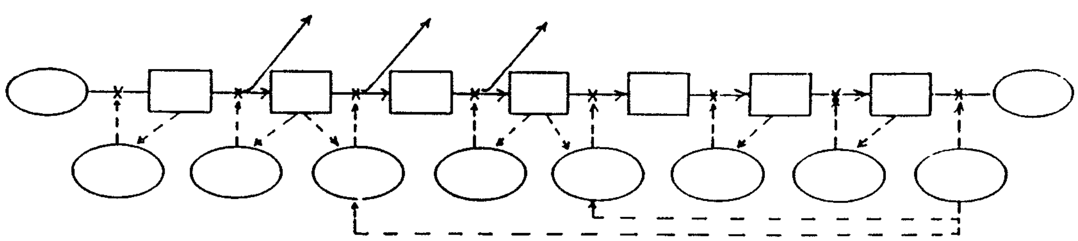
[2] D.B. Rosenfield, Implications of Cost-Service Trade-Offs on Industry Logistic Structures Futerfaces 15, Nov-Dec 5, pp. 47-59

[3] - , Simulationstechink und Fabrikbetrieb Fachtagung 1988 Berlin ISBN 3-924483-71-X



CASE A STRUCTURE OF PROCESS-LINES FIG. 1

SACHSA FIG. 2



- PUSH-PULL
  CONTROL LOOPS COVERING PUSH-PULL GAPS
- INDIVIDUAL REACTIVITY OF
  PROCESS STEPS MUST BE ADOPTED

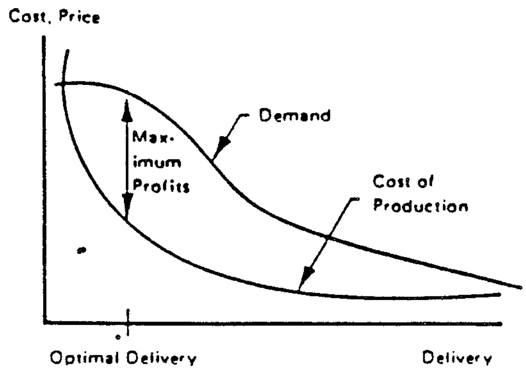


Figure 7: Choosing the cost-delivery combination to maximize profits where the upper curve is the consumers' willingness-to-pay curve (that is, demand for one unit) and the lower is the producer's cost-delivery frontier.

FIG. 3 [2]

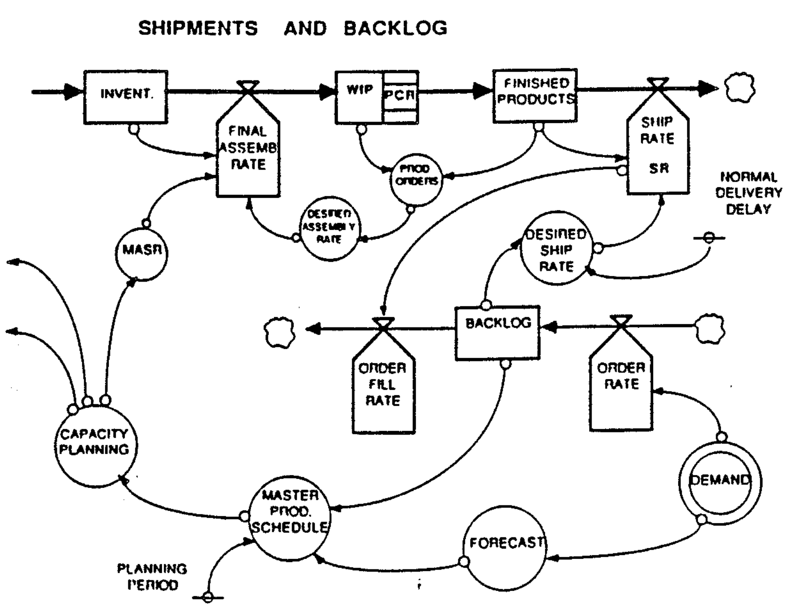
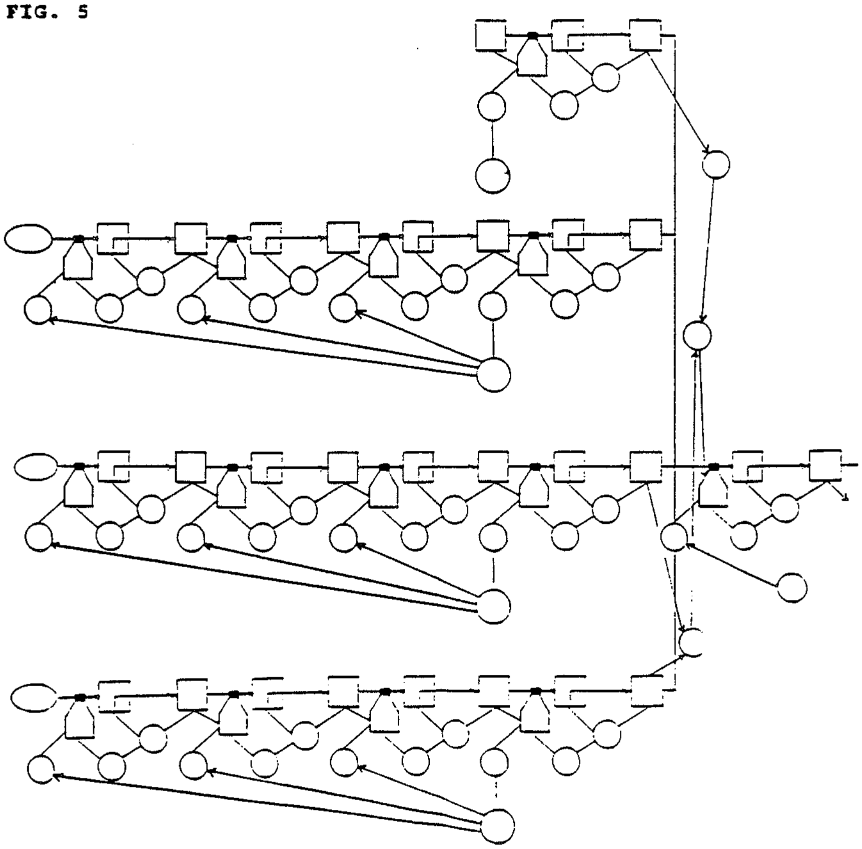


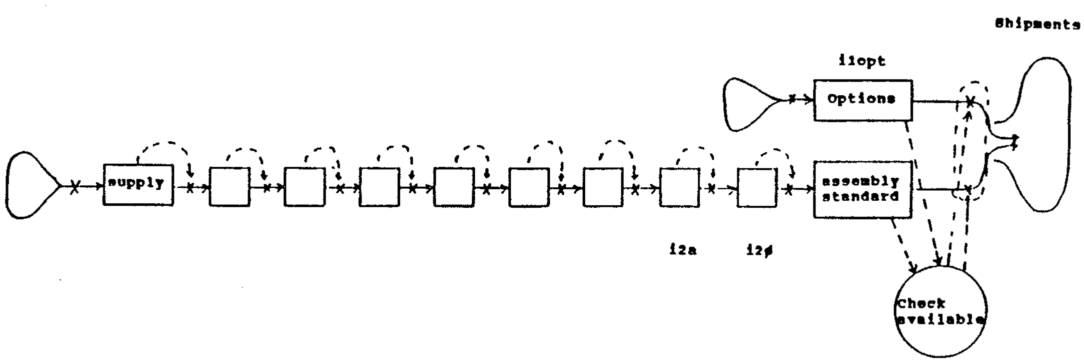
FIG. 4 REPRODUCED FROM [1]

FIG. 5



OVERVIEW MODEL STRUCTURE FIG. 6

REFS: A SYSTEM DYNAMIC PERSPECTIVE ON JIT-KANBAN [1]



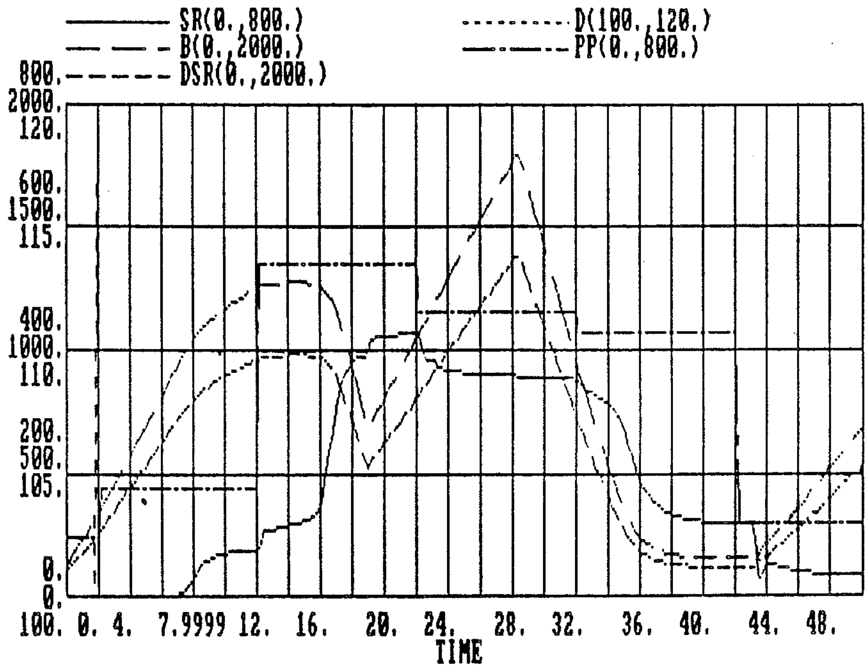


FIG. 7 RATE-CONTROL SYSTEM WITH PPT = 10
SR = SLIPMENT RATE
B = BACKLOG
DSR = DESIRED SR
D = DEMAND, PP = CONTROL SIGNAL

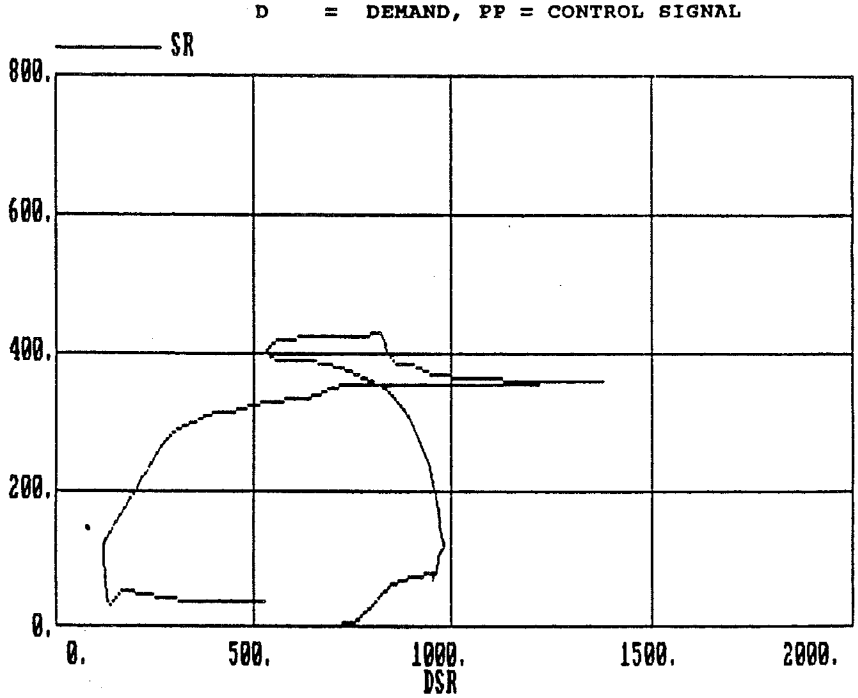


FIG. 8 RATE-CONTROL:
CONVERGENCE TEST
NOT ACCEPTABLE
PPT = 10

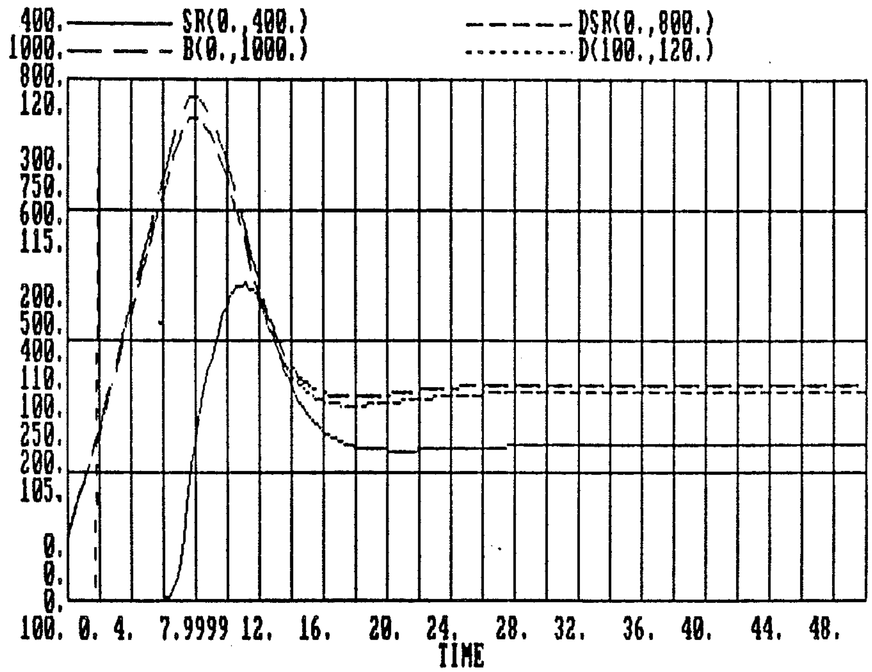


FIG. 9 RATE-CONTROL WITH SHORT PPT=2

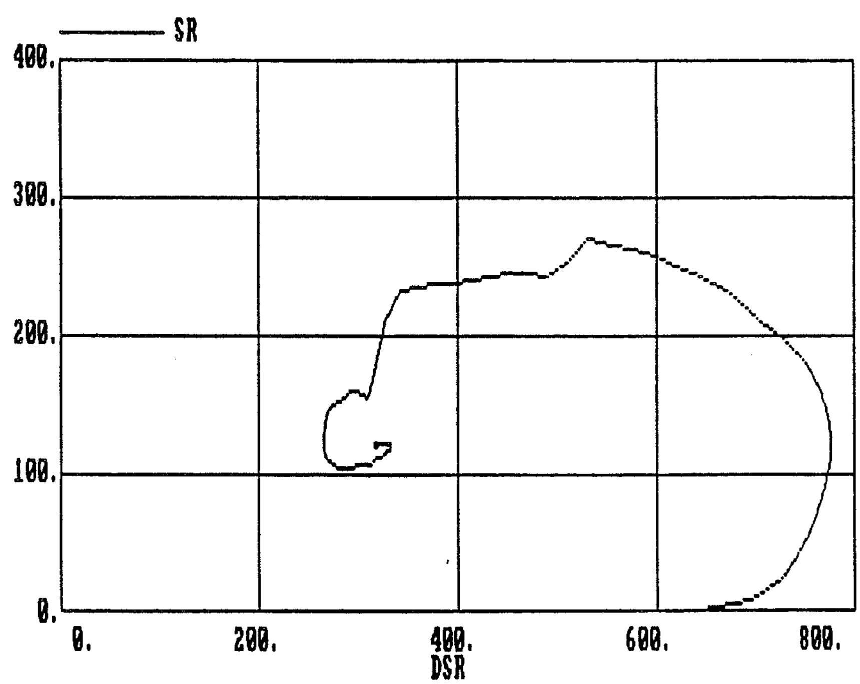


FIG. 10 RATE-CONTROL WITH SHORT PPT=2
CONVERGENCE ACCEPTABLE

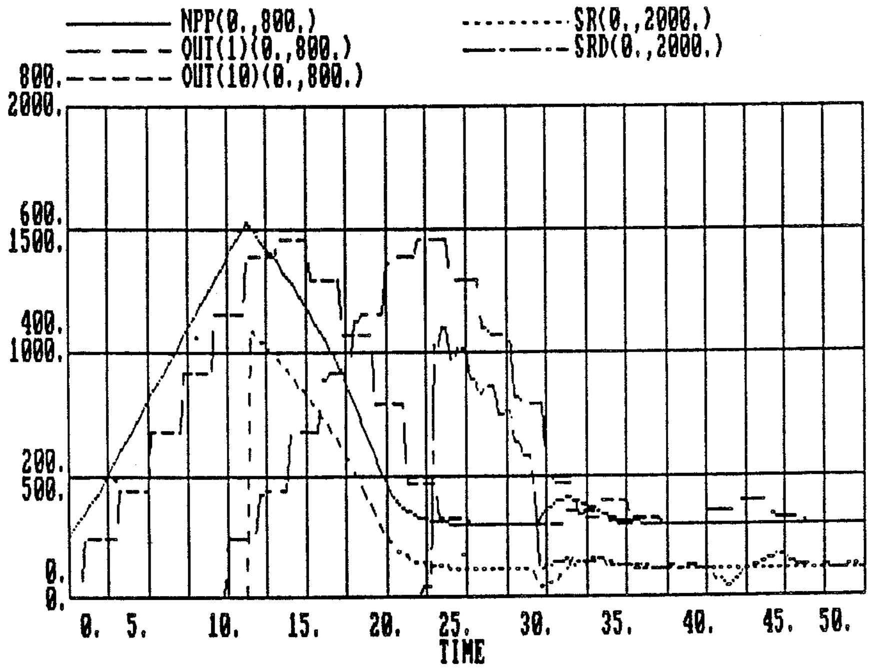


FIG. 11 VOLUME-CONTROL
EXPLANATIONS IN TEXT

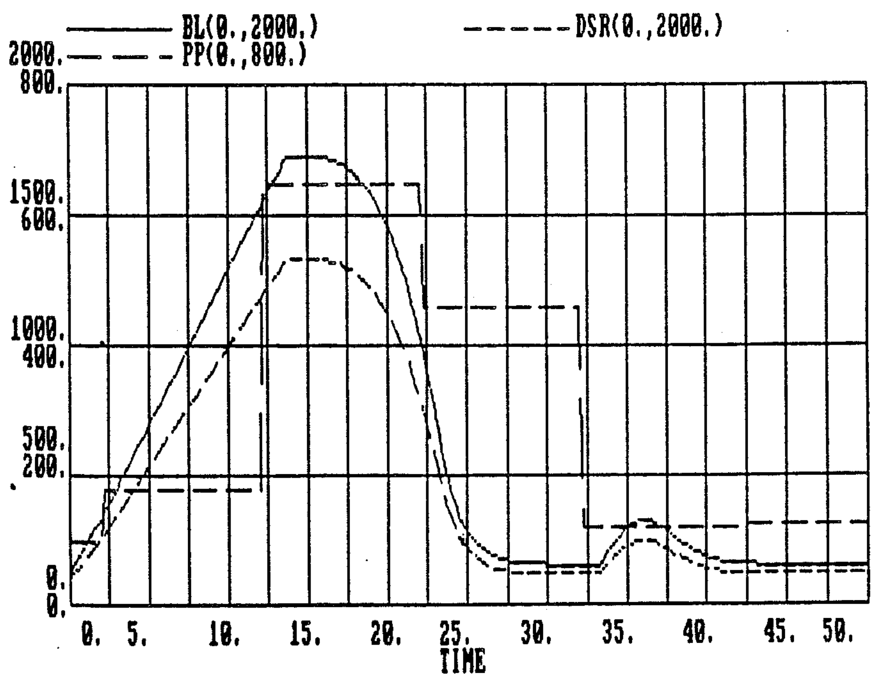


FIG. 12 VOLUME-CONTROL PPT=10
SEE EXPLANATIONS FIG. 7

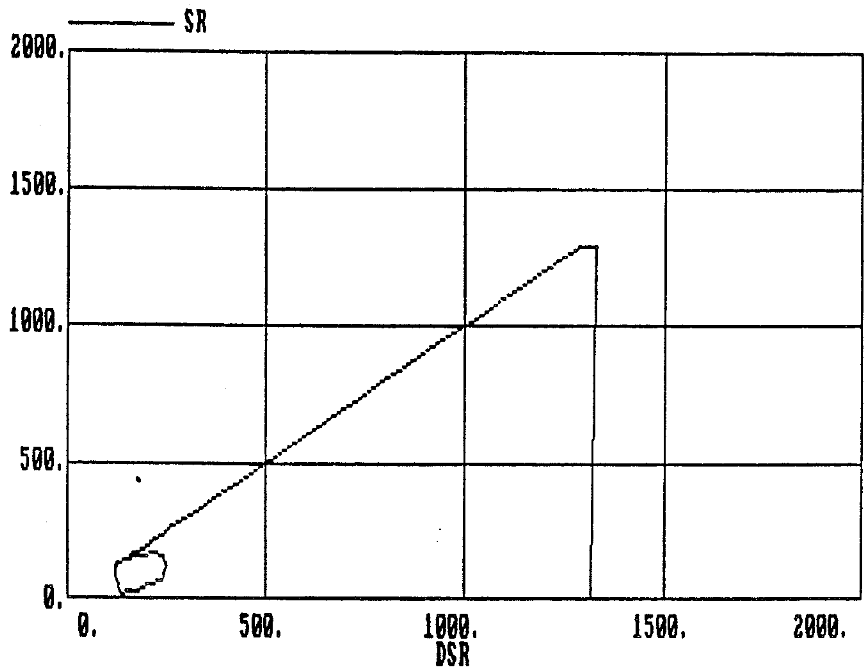


FIG. 13 VOLUME-CONTROL PPT=0
GOOD CONVERGENCE

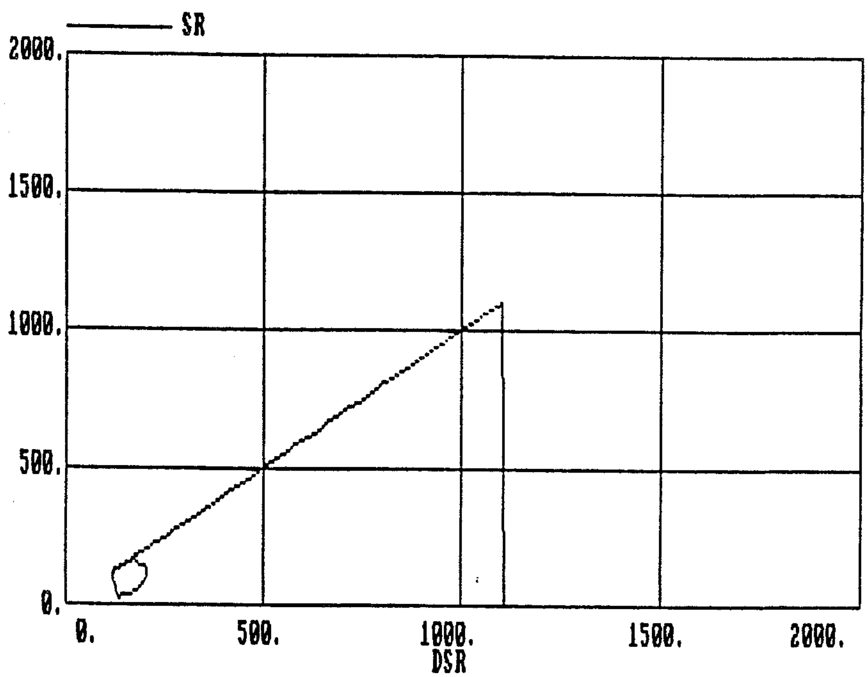


FIG. 14 VOLUME-CONTROL PPT=2
GOOD CONVERGENCE