Quasi-Analog Simulator for the Optimization of the Flow of Materials in Integrated Systems

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Summary

A quasi-analog system is described in detail which is capable of representing complex materials handling systems with a view to optimising such processes either before construction or after operation has commenced. An example is given of the savings to be made as a result of optimum handling routes, based on information gleaned from the simulation.

1. Introduction

A quasi-analog simulator [1] for the analysis of the flow of materials was developed in the Department of Materials Handling of the Ruhr University in Bochum, supported by the Ministry of Technology and Research of the state government of North-Rhine-Westphalia. This simulator allows one to describe discrete systems of handling or processing plants in a similar way to continuous systems using an analog computer. This means that handling systems can be represented by hardware model functions, the combination of simulation modules. Such a model employs the transmittance of signals which correspond to the flow of material, information and signals of the real plant.

This simulator, independent of the availability of computer systems, enables the planning personnel without specific knowledge of data processing or the employment of computer specialists to test ideas, represent the functions of a newly developed system and prove its performance to the customer. The simulator is applicable to the entire field of handling bulk materials, for unit transportation which does not require identification or information about destination during the simulation and processing plants in the chemical or steel making industry.

2. The Quasi-Analog Simulator

The core of the quasi-analog simulator (Fig. 1) is formed of three 19 inch racks for the installation of the modules. It is possible to increase the number of racks to five. Each one is equipped with its own power supply unit in the lower part and a maximum of nine module carriers each with two simulation modules. The following types of simulation modules are available:

A: hopper	(10 pieces)
B: discontinuous transporter	(2 pieces)
C: continuous transporter	(18 pieces)
D: conveyor type weigher	(4 pieces)
E: shiftable distribution	(12 pieces)
F: shiftable junction	(2 pieces)

To combine various modules, connecting cables can be plugged into the front panel of the modules.

The central equipment is installed in another 19 inch rack. It consists of the central unit, 4 random number generators, a 4 channel digital-to-analog converter and a 4 channel line recorder. The connection to the simulation modules can again be accomplished with plugged cables.

The central unit is equipped with an operating board for the control of the simulator, a realtime clock with a digital readout and two stop watches. The four random number generators allow operation with handling capacities varying between two adjustable limits. Since the simulator is internally digitally organized, it is necessary for the analog registration to transpose the digital data into analog signals before recording.

To represent a system visually and to facilitate operation, a luminous circuit diagram built up from mosaic elements is available. Control and recording elements built into the screen are connected by cables from the rear to the modules. An alteration of the system can be carried out in a short time by exchanging elements.

The simulator can be connected to a process control computer to register the digital data or to control the process.

3. Application of the Quasi-Analog Simulator to a Ship-Loading Operation

The ship-loading operation in an integrated ore handling plant serves as an example for the application of the simulator (Fig. 2). The investigation was carried out with the goal of developing a new strategy to reduce the demurrage time of ships and to utilize conveyors in the loading area up to their capacities. Economical aspects and solutions in the design will be considered in a later stage.

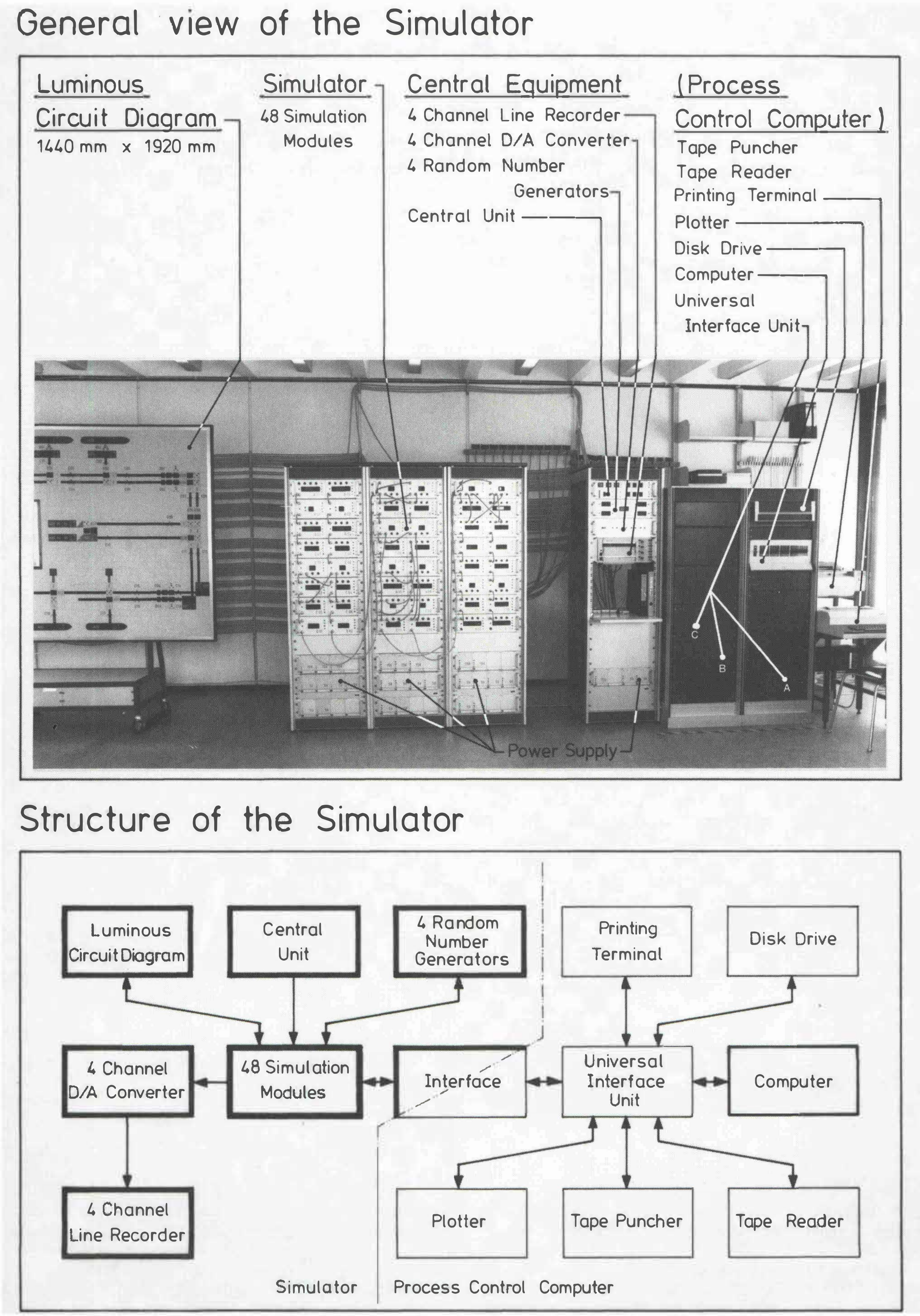

Fig. 1: Quasi-analog simulator for handling operations

Aerial view

Conveyor roads

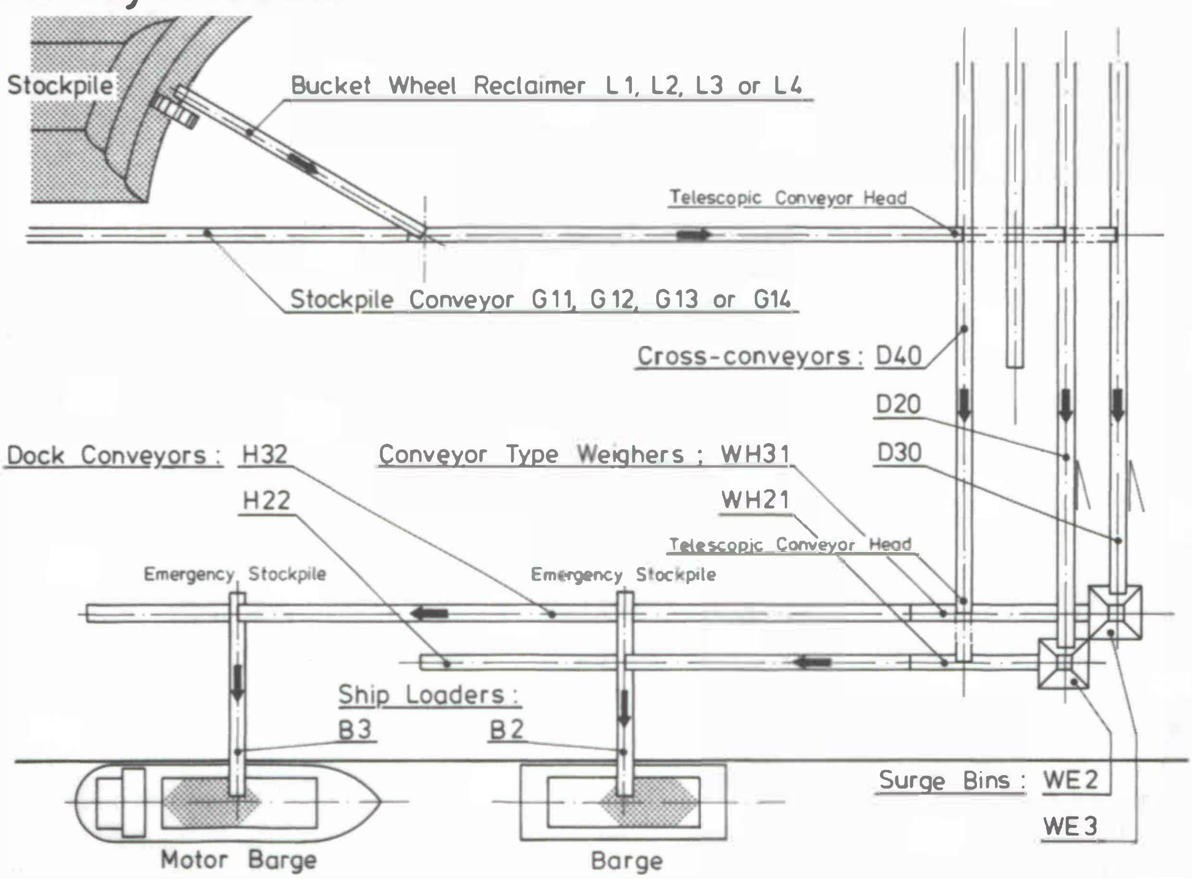

Fig. 2: Existing ore terminal

The present status of the ship-loading facilities is the basis for the analysis and therefore the way a single ship is loaded shall be described in detail.

At the beginning of each loading operation the quantity of ore which can be charged to a ship or a barge depending on its nominal capacity and the present draught of the canal is to be determined. About 90% of the required amount of ore will be requested from the bucket wheel reclaimer as the basic quantity. The conveyor line between the reclaimer and the ship loader (Fig. 2) will be selected. A choice of two alternatives exists in the area of the cross-conveyors:

1. Transport via the cross-conveyer D 40 and its telescopic head onto one of the two dock conveyors H 22 or H 32, by-passing the surge bin.
2. Transport via the inclined cross-conveyor D 20 or D 30 respectively into the surge bin WE 2 or WE 3 respectively which are connected to the dock conveyor H 22 or H 32 respectively.

After selecting the conveyor system the individual conveyors will be started in sequence beginning with the ship loader. As soon as the last conveyor reaches its nominal speed, the corresponding bucket wheel begins to reclaim the basic quantity from the requested stockpile. When this is concluded the bucket wheel operator has to wait for the order to reclaim the necessary quantity for trimming the ship. This quantity can only be determined when the basic amount of 90 % of the capacity has completely arrived at the ship. The trim position of the ship will then be determined by measuring the free board on the four corners and the requested trimming quantity can be calculated. This requires a length of time of at least one minute and is to be added to the conveying time to determine the total waiting time for the bucket wheel reclaimer, after which the operator can resume reclaiming the trimming amount. When this is completed the conveyor line remains in operation until this quantity has completely arrived at the ship.

As the result of these considerations two statements can be made to develop a new strategy:

1. When the trimming quantity for the ships is reclaimed by the bucket wheel from the stockpile, extended waiting periods for the equipment and corresponding idling of the conveyors is caused.
2. The hoppers were not utilized as surge bin to save energy for the lift of the material. Consequently the varying performance of the bucket wheel and interruptions caused by the conveyors prolongated the employment of the dock conveyors and the ship loader.

To analyse the operation, the plant was represented by lining up the simulation modules for hoppers, reclaimers, conveyors and ship loaders. Furthermore, the process control computer was connected with four simulation modules to record the quantities handled during the loading period (Table 1).

The simulation of the loading operation was carried out for three case studies:

— direct loading without surge bin
— loading including surge bin
— new strategy introducing trimming hopper.

The actual performance of the reclaiming operation of the bucket wheel with representative breakdowns or interruptions was recorded in an existing ore terminal, stored in the disk of the process control computer and was reproduced in all three cases to compare the reality with the simulation. These three cases are demonstrated by the loading operation of the barge "Krupp 27" as an example.

Ore Terminal		Measuring Point	Simulator	
Weighing Idler in Bucket Wheel Reclaimer	L 1	1	Module	D 01
	L 2			
	L 3			D 02
	L 4			
Weighing Hopper on Loading Dock	WE 2	2	Module	A 07
	WE 3			A 08
Conveyor Type Weigher on Loading Dock	WH21	3	Module	D 03
	WH31			D 04
Weighing Idler in Ship Loader	B2	4	Module	A 09 *)
	B3			A 10 *)

Table 1: Equivalent Measuring Points

*) The simulation module "hopper" at the end of the conveyor line represents a ship and in addition takes over the function of the weighing idler in the ship loader.

The first case was plotted in Fig. 3. The bucket wheel reclaims the basic load of 90% of the nominal capacity of the barge depending on the permissible draught for the present water level. After a time lag of about five minutes the material arrives on the dock conveyor and is recorded by measuring point 3. Four minutes later it arrives on the ship loader, recorded by measuring point 4. After completion of this phase, the reclaimer has to wait until this basic load has arrived in the ship and the trimming quantity is determined by measuring the free board of the barge. When this information is received by the operator, reclaiming is resumed and the requested amount of ore will be conveyed to the ship loader, where it arrives with the same delay of nine minutes, which is based on an average length of travel from the position of the bucket wheel in the yard.

The result of research for case one was, that the waiting time amounted between 10 and 25% of operating time for the bucket wheel reclaimer.

The second case applies the surge bin and the result is plotted in Fig. 4, to indicate reduction of operating time of loading dock conveyors and the shiploader. This strategy is based on the following measures:

1. the surge bin is utilized to store the unsteady flow of material from the reclaimer and to feed it with the constant rate slightly above the average input onto the dock conveyor
2. when a certain level of the hopper capacity is reached, the feeding conveyor is started.

Fig. 4 shows that about 10 minutes after the beginning of the reclaiming, the dock conveyor leads the material with its full capacity to the ship loader. When the basic load has reached the barge the surge bin is emptied. Thus the period of utilization of the loading equipment on the dock is greatly reduced.

Now the same waiting period for determining the trimming quantity takes place again with the same lost time for conveying the trimming quantity from the bucket wheel to the ship loader.

In the third case the system will be altered to avoid this waiting period by arranging trimming hoppers in the im-

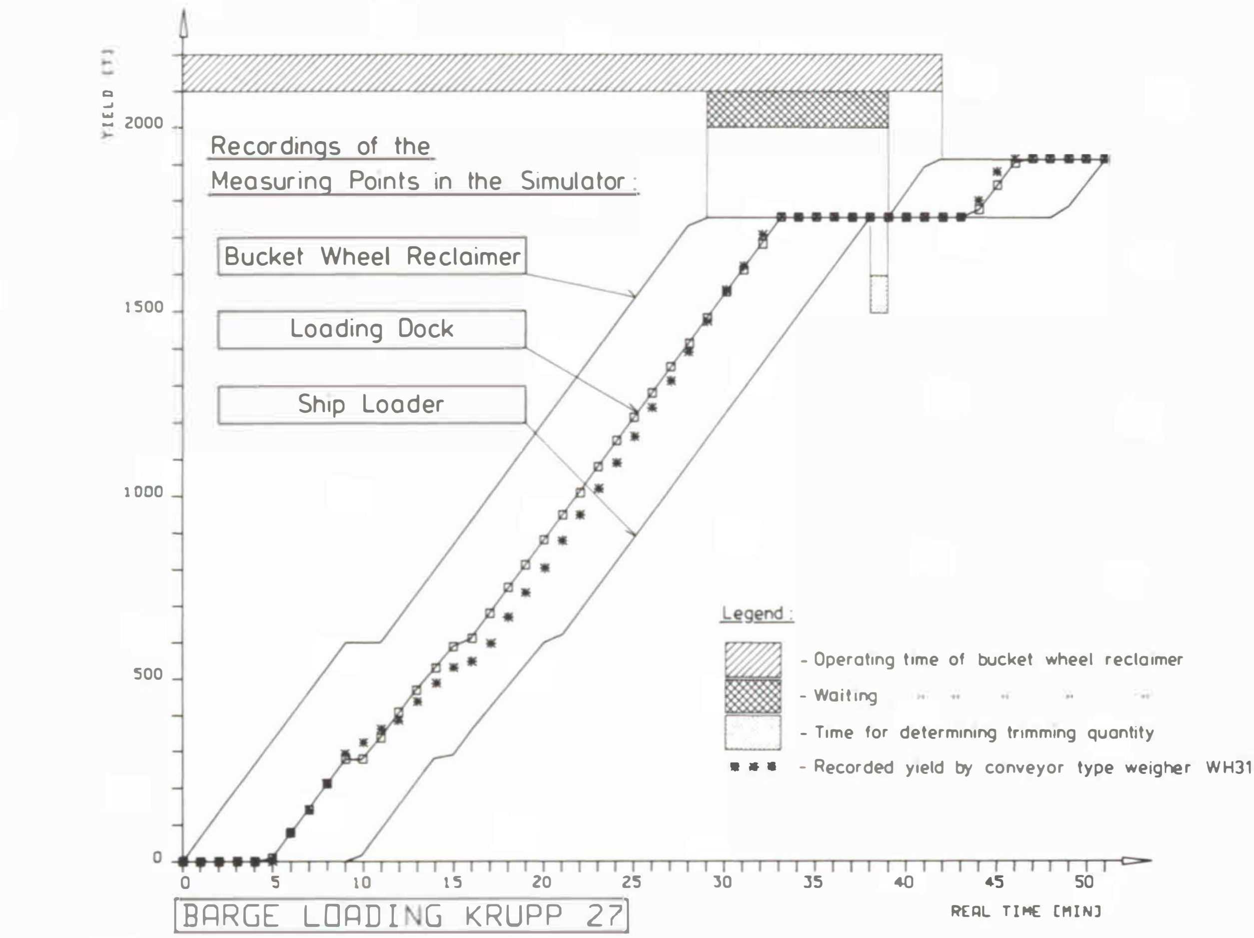

Fig. 3: Recording of measuring points in the reconstruction of the initial state

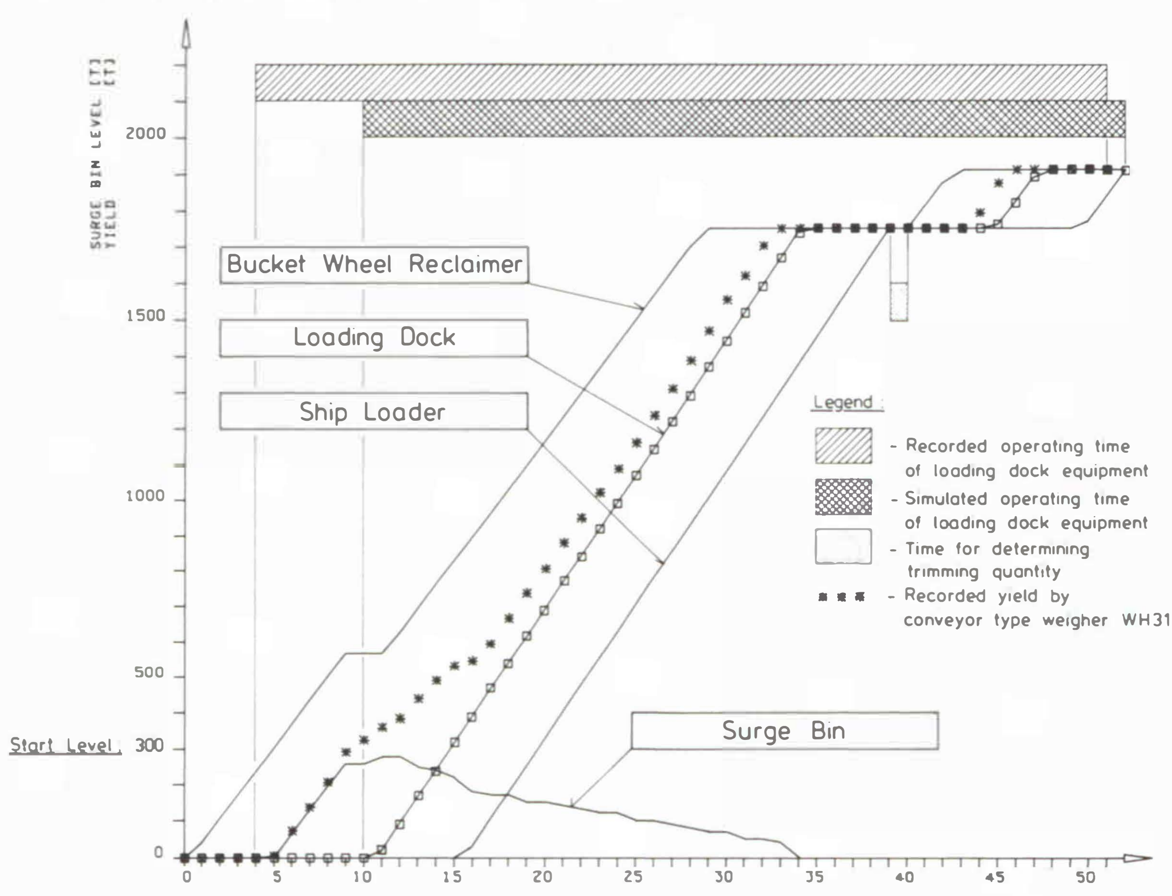

Fig. 4: Changes in the system behaviour with the incorporation of a surge bin

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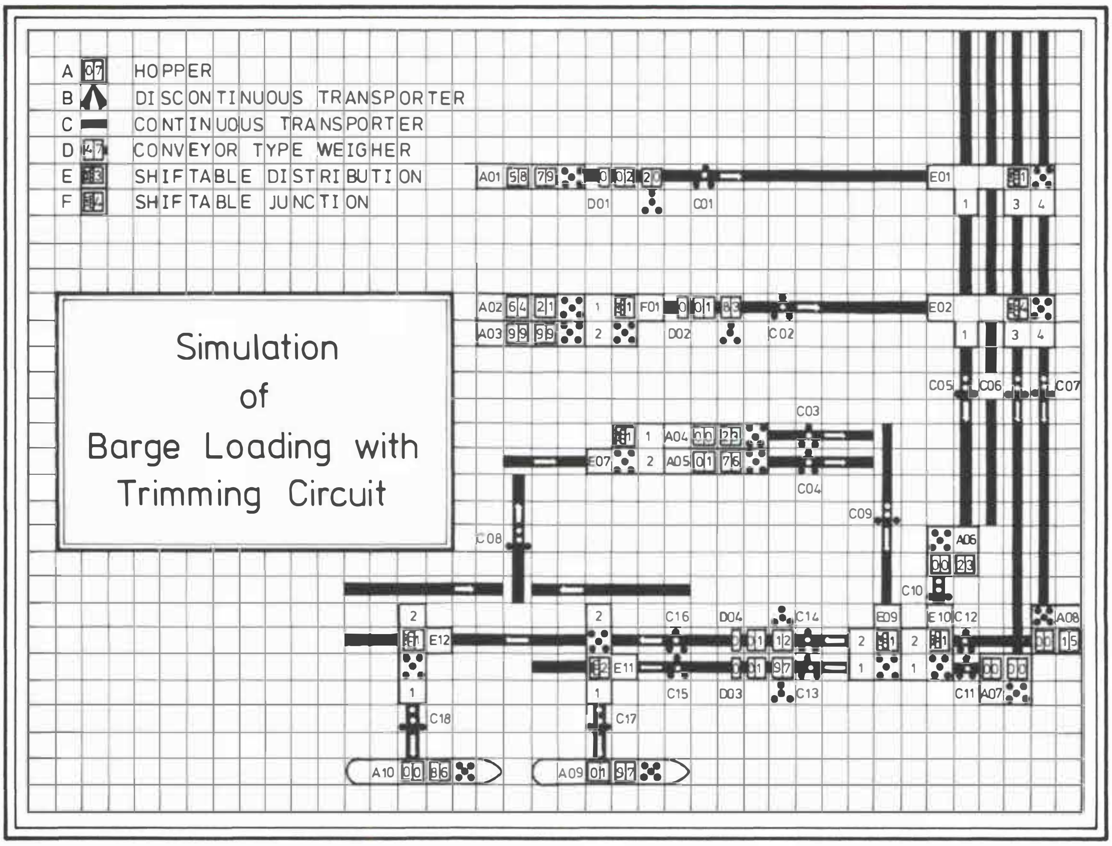
Luminous Circuit Diagram



Interconnections

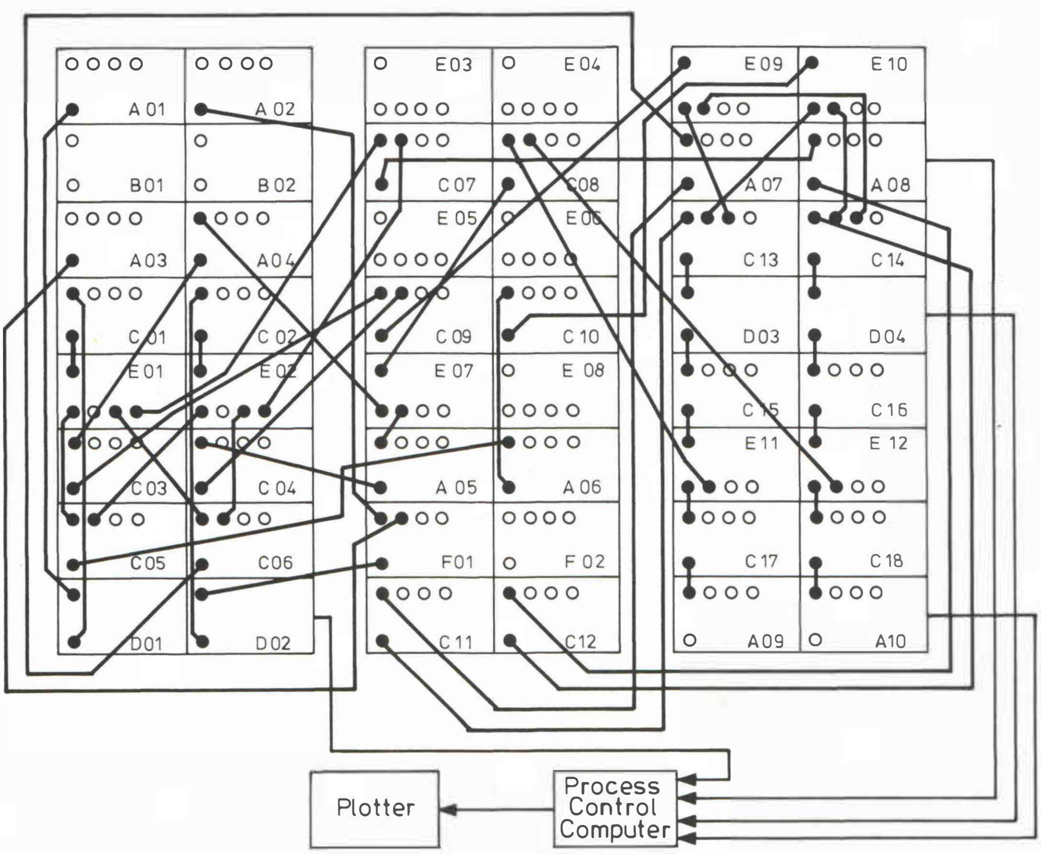


Fig. 5: Example of circuits: Barge loaded with trimming circuit

mediate vicinity of the dock, as shown in Fig. 5. This strategy applies the following pattern.

- The bucket wheel reclaims the full nominal capacity of the barge.
- The conveyors carry the material with the same fluctuating rate to the surge bin.
- When the start level is reached the output conveyor feeds the material with the optimum capacity onto the dock conveyor.
- When the conveyor type weigher on the loading dock indicates 90% of the barge capacity, the feed conveyor is stopped.
- The trimming can take place from the remaining load in the surge bin.
- Is there a quantity in excess of the requested amount for the trimming, it will be fed to the adjacent trimming hopper for this special type of ore.
- Is there a shortage, i. e., the surge bin capacity is lower than the requested amount for the trimming, this quantity will be taken from the trimming hopper.

Thus the waiting time to convey the trimming quantity from the bucket wheel to the dock conveyor can be saved. This procedure naturally is only necessary when each barge will be loaded with a different type of ore. If a complete pushing unit of four barges will be loaded with the same type of ore, this procedure will be applied only for the last one.

The saving of time using the new strategy would be placed between 13 and 21% of present operating time for single barges and between 17 and 24% for a pushing unit of four barges.

4. Summary

The utilization of the simulator for the example of a shiploading operation indicates its applicability for planning a bulk terminal or for optimizing operations in an existing plant.

This simulation proved that the following results can be realized:

- analysis of an existing or planned handling system
- improving the layout of a plant and its components
- optimation of the system or subsystem
- inexpensive and fast testing of a plant, at no risk
- prediction of the behaviour of a system before start up
- training of the personnel for a plant in the project phase
- testing of the process control program before the actual operation
- check up of alterations in the construction phase
- presentation of the system as sales promotion

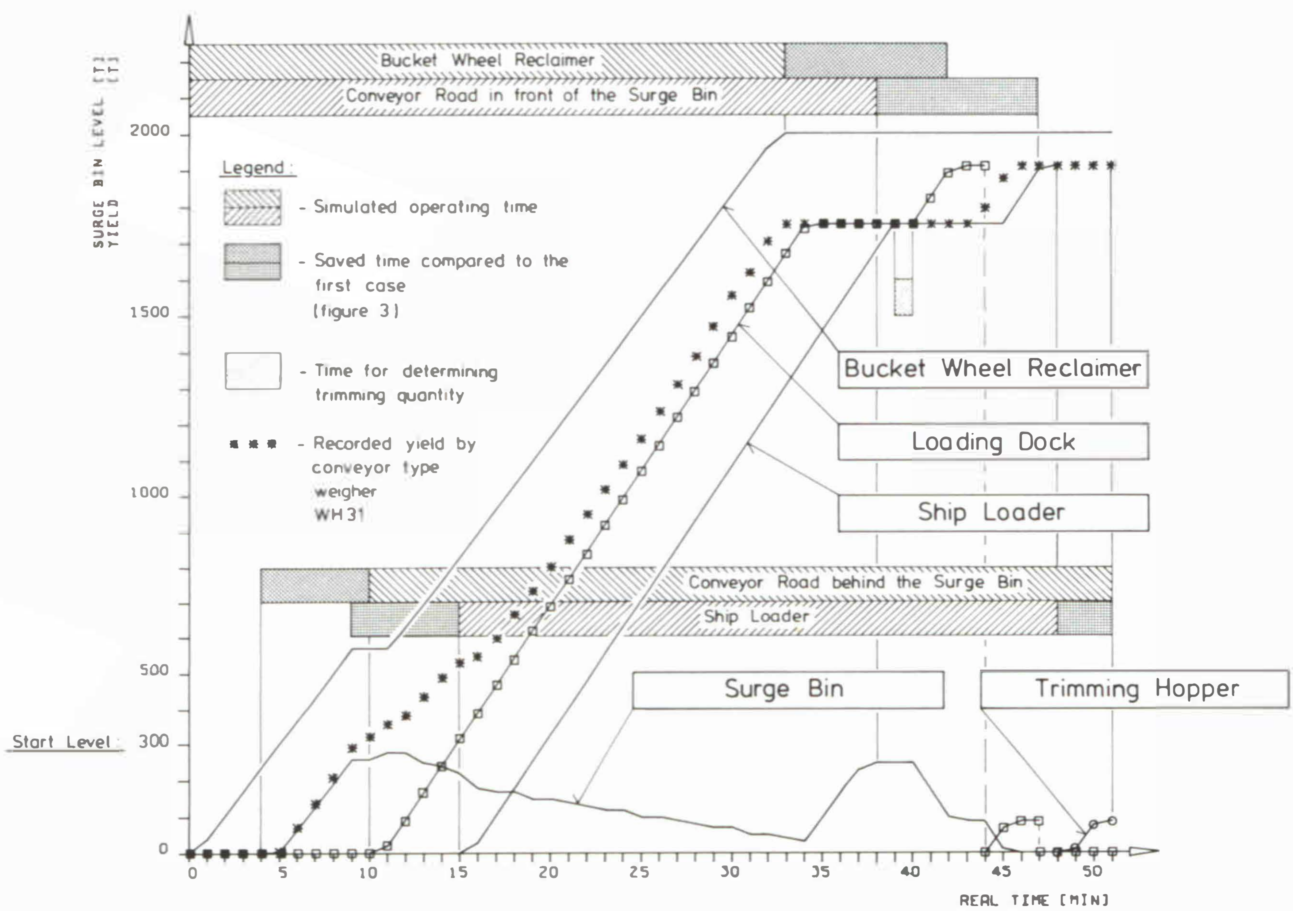


Fig. 6: Changes in the system behaviour using the trimming circuit approach

In comparison to numerical computer programs the simulator offers as an analog model many advantages:

— all simulation modules function in parallel
— the model can be altered manually in a short time
— the model can cooperate with real components
— simulation can be carried out in realtime or time compression or alternatively:
— simulation is done in immediate contact with operator and equipment
— results are plotted, punched or printed during simulation
— sequence of operational events is self explanatory since it is observed online.

The only disadvantage of hardware simulation in comparison to numerical programs is the limitation of the number of available modules (similar to analog computers). This problem can be overcome by subdividing or by simplifying sophisticated systems, whereby the identity with the real system will not necessarily be reduced.

Acknowledgements

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References

[1] Riechelmann, G. H., "Quasianaloger Materialfluß-simulator — Ein Instrument zur Untersuchung von Betriebsabläufen in komplexen fördertechnischen Systemen", Heft 82.1 der Schriftenreihe des Instituts für Konstruktionstechnik der Ruhr-Universität Bochum, Lehrstuhl für Maschinenelemente und Fördertechnik, Bochum 1982