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CO-ORDINATION - A SYSTEM BRINGING REAL TIME
ECONOMIC PERFORMANCE CONTROL TO FERTILISER PRODUCTION

TA/84/22

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The Background

Fertiliser producers are attempting to adapt to fast changing business conditions with existing plants and traditional Process Management techniques. Over-capacity, the emergence of Middle Eastern production based on cheap feedstocks, and a world economy which has foresaken the business cycle for a rollercoaster, have all contributed to squeezed profit margins and a rash of Plant closures.

The Problem

Fertiliser producers must reduce their production costs whilst improving both quality and their flexibility of response to changing market conditions.

Our Solution

ICI has developed a computer-based information monitoring system, capable of bringing improved production efficiency to new and existing Plants.

This system enables dramatic cuts in variable costs to be made by co-ordinating the entire Production Management decision-making process. It raises the focus of attention of Management and Plant Operators to economic objectives rather than just individual Plant measurements.

The Reasoning

The Company's newly-formed Engineering Department - itself a product of efforts to cut fixed costs and improve effectiveness - carried out a feasibility study into the opportunities opened up by micro-electronics in process control. They concluded that merely replacing old-fashioned conventional control systems with more modern equipment was failing to address the real problem.

Such equipment will maintain pressure, control temperature and hold production levels steady - its replacement with new control instrumentation may also bring increased reliability and great flexibility - but that's all. The variables mentioned bear little relationship to the need for the economic performance of Plant.

The system envisaged in the late 1970's by Engineering Department was to be capable of real time evaluation of complex production issues and resolution of often conflicting Plant priorities, whilst at the same time it was to present the information in easily understandable terms.

But what easily understandable terms? How were Management to balance the relative importance of catalyst problems against degraded machine performance or quality control?

The only commonly understood basis for the measurement of performance is economic. It was by starting with this approach that ICI was able to achieve what it later termed Economic Performance Control. That required the integration of cost and production information and this was vital if the system was to be successful.

The concept was fine. The problem was, who amongst the equipment hardware (and software) producers had the capability to meet such a requirement? The system Engineering Department wanted would reconcile Production issues such as trying to stabilise the Plant to run at optimum efficiency with marketing issues such as variation in demand. This was really breaking new ground, bridging the gap between Plant-based process control and the business-based Management information systems. The end result was to provide Operators and Management at all levels with much clearer insight into production performance. This instantaneous measure of performance would then encourage the exploitation of short term profit opportunities.

It soon became apparent that existing control and instrumentation suppliers' expertise to address such diverse issues was too narrow. However, ICI's own Engineering Department was ideally suited to pull together the various strands of technology. Software, computer hardware, instrumentation, electronic interface systems and control engineering skills were all available in-house. More importantly, the Department had access both to production units and to the Business Management organisation and could understand the problems.

The Result: Co-Audination

Fifty man-years of development by Company Engineers has resulted in not just one system, but three. Starting with a system known as Auditor for economic performance control of individual Plants, the system can be built up in progressive stages through Co-Audinator for area monitoring and can be completed by Super Co-Audinator for a real time information network capable of controlling giant chemical complexes, sometimes hundreds of miles apart. This integrated package is used within Agricultural Division to achieve just this result.

FIG1. COAUDINATION.

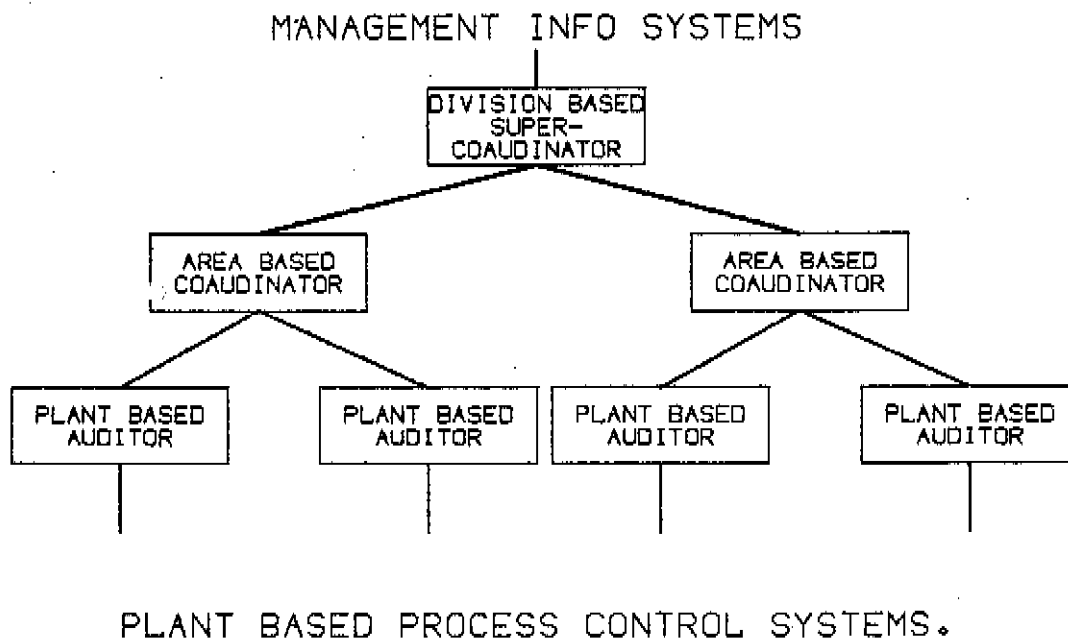


Fig 1

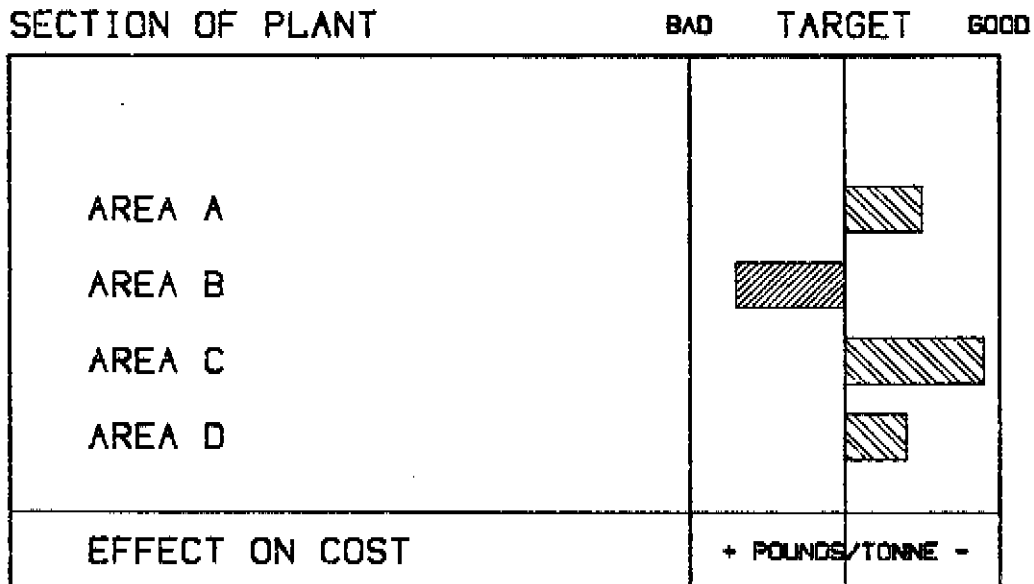
Auditor

At the base of the information pyramid is Auditor. Designed for application at Plant level, the system enables the discrete process variables - steam, pressure, temperature, etc. to be gathered. The data can then be used to calculate performance of specific equipment in the Plant against the relative performance of other sections. Since all indices can be related to a common economic base, operating priorities clearly emerge.

The information, which is refreshed every few seconds, also has the additional benefit of giving staff a feel for process dynamics and an immediate feedback on the effect of their actions.

Early in the development phase, it was recognised that to gain maximum value from Auditor, Process Operators and Managers must feel motivated to take the actions required for economic performance control. To achieve this, all information is displayed in easily assimilated graphic, bar chart, trend and specially designed performance versus target displays.

FIG 2. ECONOMIC PERFORMANCE VS. TARGET



The flexibility of the system to adapt over a period of time to the changing needs of Production Management was considered important, therefore the system is designed to be easy to configure and programme. The user needs only to undertake a simple computer prompted table-filling exercise, or, at most, programming in a pre-structured form of BASIC, to exploit the power of Auditor.

To give the user confidence to undertake this task, the system is fault tolerant, enabling him to recover from an error. In the past, the need for, and difficulty in, getting a computer expert to do this task has often meant the system soon became out of date and irrelevant to the user's needs.

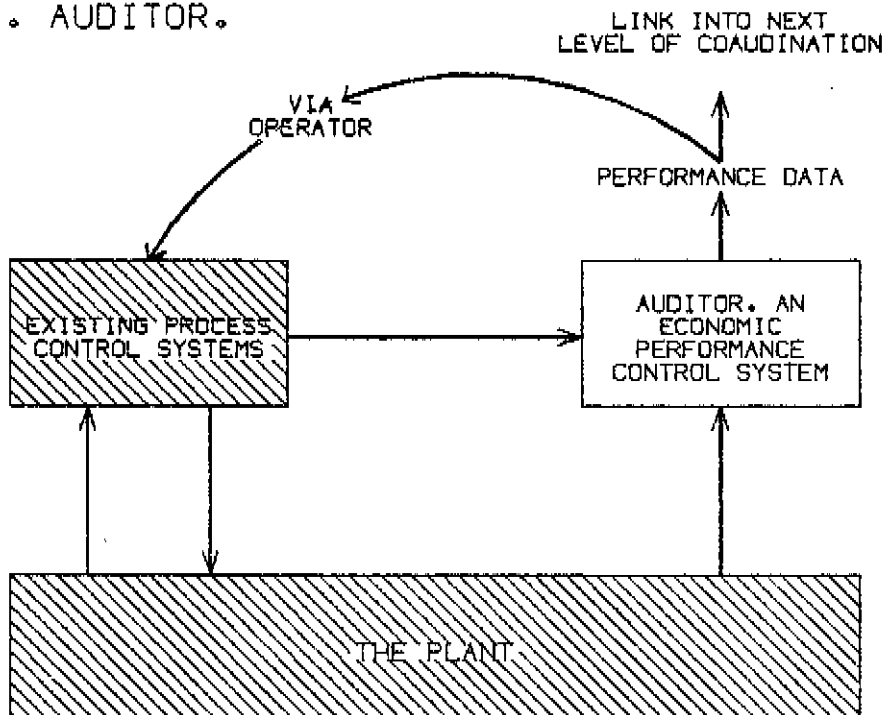
Since starting with a trial installation some 3 years ago, Auditor has now been fitted to 50 different Plants in ICI, ranging in size and type from ammonia and Nitric Acid production through to pilot Plants and water treatment facilities. Further installations throughout ICI are now being sanctioned at the rate in excess of 2 per month, but it is Agricultural Division which has taken up the use of Auditor the most quickly and most comprehensively. Systems have been installed at the Division's Billingham complex, at their Fertiliser Works at Severnside, near Bristol, and at Immingham, on Humberside, and this at a time of cash constraints which demanded a six month payback on investment of this type.

Auditor's Role in ICI Ammonia Production

One of the first, and still the largest, product sectors to benefit from Auditor was Ammonia. As such, it is an excellent example to illustrate just how the system has been put to everyday use.

ICI now has Auditor on all seven of its Ammonia Plants operated in the UK. The Plants use different process control systems ranging from pneumatic to the most modern electronic system. In all cases, Auditor gathers data from the existing systems without the need for expensive reinstrumentation.

FIG 3. AUDITOR.

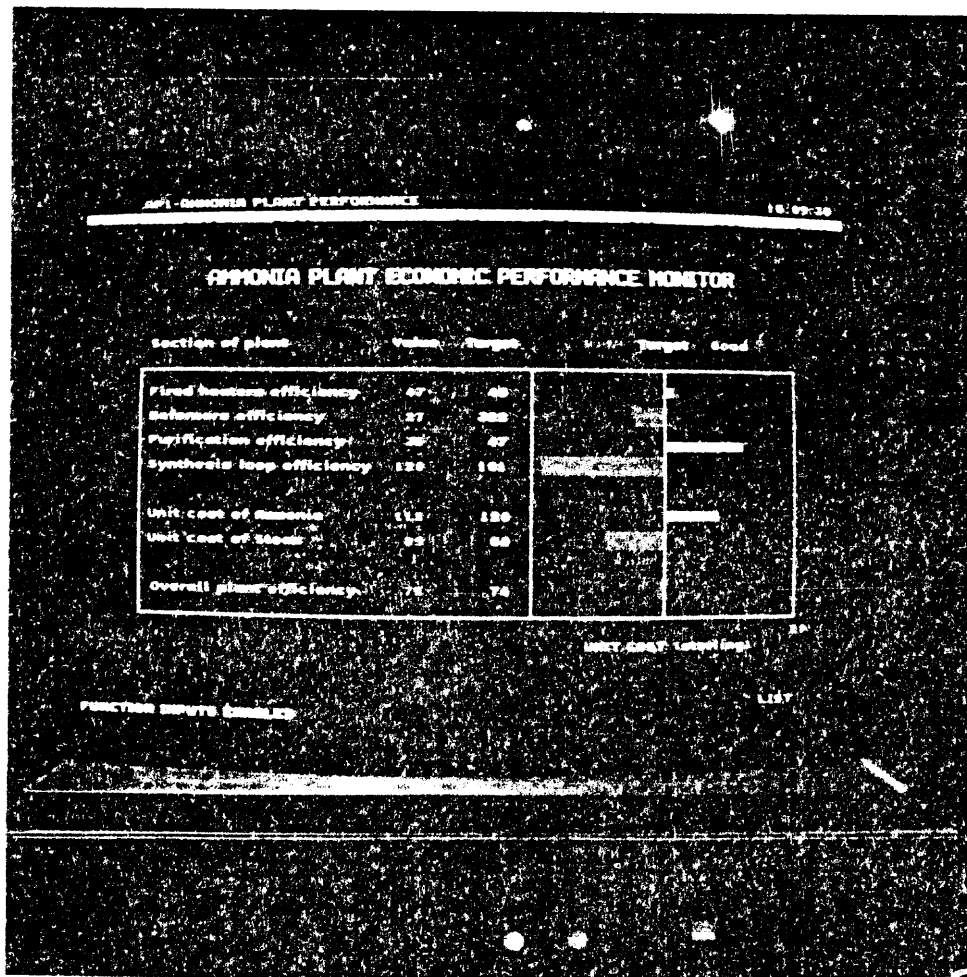


The Ammonia Plants use different process technology and so detailed economic performance calculations vary from Plant to Plant. However, on all Plants, overall Plant efficiency is calculated, together with the efficiency of each individual sub section - in particular those relating to energy usage.

These instantaneous efficiencies expressed in Giga-Joules per tonne of ammonia exported are continuously displayed and used in all daily reports. This derived data is then averaged over each shift and working day for future analysis. Raw material use and ammonia make are also automatically mass flow corrected and integrated in the daily report.

This performance data is then compared with target values; if a deviation occurs, then Auditor displays highlight this and effectively lead the Operator to the specific area of the process responsible for the deviation. For example, performance versus target displays are used to help optimise the convertor, particularly during start-ups. Then later, as the catalyst ages, the target values are adjusted in line with its activity to ensure that the display remains meaningful and the objectives realistic. The principle is to provide relevant information not available from existing instrumentation.

Fig 4



To avoid the need for difficult online analysis, yet to provide greater insight into process performance, Auditor is used to perform a mass balance around the synthesis loop. Based on a theoretical model and the availability of certain easily monitored data, the system can infer other values and thus generate a picture of the percentage of each component in the loop. Iteratively solving the equations and averaging the results can minimise the effect of noise and errors in the primary data. The H_2/N_2 ratio is particularly important and is used by the Operator to fine tune the Plant.

In practical terms this parameter is difficult to make available by other means on a continuous basis.

Every process measurement and calculated value in the Auditor database is archived at a configurable interval. These values archived over the previous few weeks can then be compared with other information in the file. To highlight trends and enable events to be correlated, this data is presented as a three pen chart recorder. For example, trend plots are produced of the production rate and put alongside, on the same time base, plots of the Plant efficiency.

Digital events can be similarly archived, together with an individual time tag. This enables, for example, post mortem analysis of Plant trips and clearly indicates the sequence of events.

This data retrieval facility is an invaluable aid when trying to analyse the cause of Plant problems. Furthermore, if Plant upsets are handled efficiently, it is possible to retrace the course of events and consolidate experience.

However, if equipment failure or external influences do take their toll of production, Auditor's economic performance capabilities are on hand again to undertake a loss - accounting calculation in an attempt to estimate the total cost of interruptions. For example, loss of performance of any of the main Plant items can be used to trigger the loss account. Then the cost of wasted natural gas and lost profit on the Ammonia which should have been produced is integrated over the period and is used in the Plant Manager's report.

Changes in production rates to react to market conditions introduce two major problems - both of which have been overcome on the Ammonia Plants with the aid of Auditor.

The first problem is to determine the best choice of setpoints for the key process variables to most cost effectively control the Plant at the new level of production. Experiments to determine the optimal setpoints are easier to implement and analyse using Auditor.

The second problem is how to move the production rate to the new level without adversely affecting Plant efficiency. On the ICI Ammonia Plants, the Operator is presented by Auditor with a series of seven recommended setpoint changes allowing a move to higher or lower production levels with the minimum of disturbance to the process.

The quantity of natural gas available for Ammonia production is sometimes restricted, particularly during the winter. Each morning, the daily allocation of gas available, together with its calorific value and specific gravity is passed to the Plant Auditors. At 60 second intervals, Auditor calculates the total natural gas used. Then, based on the current rate of gas consumption, it predicts the daily total and the quantity of gas that will be over- or under-used. At the same time, a new target consumption rate is calculated and displayed to allow the daily target consumption to be achieved in the most economical fashion. These techniques are similarly used to manage production on a limited demand basis.

In spite of the scope and flexibility available from the individually operated Auditor, the equipment was designed by ICI as only the first tier of an integrated production system operating under the umbrella name of Co-Audination.

Co-Audinator

Above Auditor in the information network is a system known as Co-Audinator. Gathering real time information from the Auditors, while also drawing in a raw data from common services not normally owned by a single Plant, the system gives a more refined, yet still instantaneous, picture of an entire production area. This broadening out of the production picture makes Co-Audinator ideal for the Management organisation of a business area - typically consisting of a small group of Plants with associated common services. It is not just a system for receiving information - Co-Audinator is designed to bridge the gap between Plant-based Auditors and the general Business Management system and can also pass information between Auditors, making it a real time link between all the processes in its network.

Such a system has been in operation at Agricultural Division's Redwick Works at Severnside, near Bristol, for one year now, and effectively provides a focal point for co-ordinating Production Management decision making. A two-phase project is currently underway to extend this system to encompass the entire Works, including its Ammonia, Nitric Acid, Phosphoric Acid, Nitram and Compound Fertiliser Plants. (See Fig 5)

FIG 5. COAUDINATOR
AGRICULTURAL DIVISION'S REDWICK WORKS

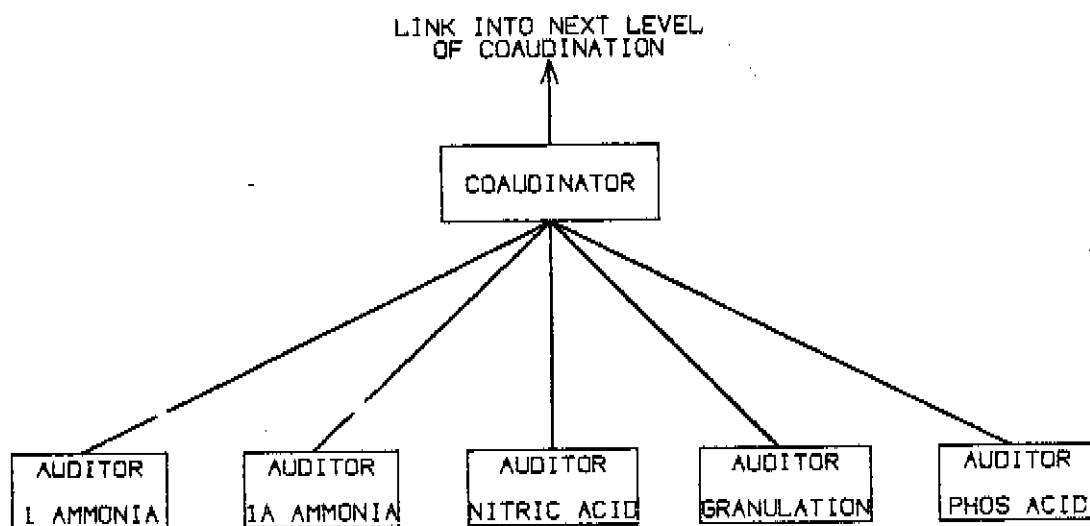


Fig 5

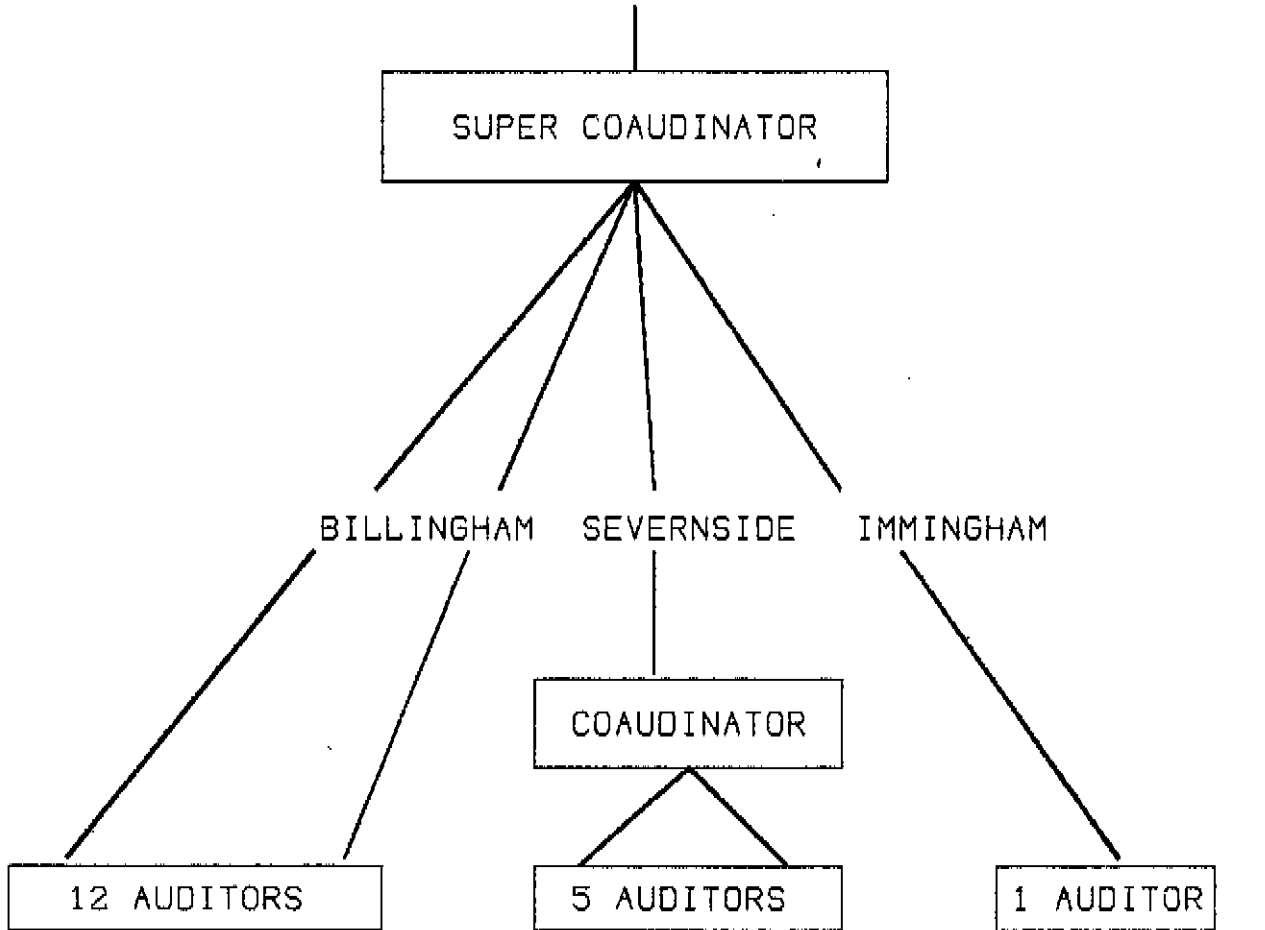
Super Co-Audinator

At Agricultural Division's headquarters in Billingham is sited their Super Co-Audinator system - the top of the real time production information network.

Called the Operations Centre, the system acts as the nerve centre for the whole Division's production performance. Plant Auditors located within 5 km are connected to the centre via a very high speed local area network, while remote Co-Auditors and Auditors situated at Severnside and Immingham are connected through the telephone network. (See Fig 6)

FIG 6. SUPER COAUDINATOR
 AGRICULTURAL DIVISION OPERATION CENTRE

LINK TO MANAGEMENT INFO. SYSTEMS



MONITORING:-

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- 4 AMMONIA PLANTS
- 1 UREA
- 2 CO₂ PLANTS
- 3 NITRIC ACID PLANTS
- 1 PHOS ACID
- 2 METHANOL PLANTS
- HYDROGEN RECOVERY PLANT
- 2 PACKAGE BOILERS
- COMPOUND FERTILISER PLANTS
- 6 SUB STATIONS

- 2 AMMONIA PLANTS
- NITRIC ACID PLANTS
- COMPOUND FERTILISER PLANTS
- PHOS ACID
- ELECTRICAL DISTRIBUTION
- GRANULATION

AMMONIA PLANT

Within the Centre, a team of Shift Managers is responsible for co-ordinating production across the Division to ensure the best overall level of economic Performance Control.

Control from the Centre takes three forms:

- 1 Reacting to a new situation on a time scale of less than an hour - for example, site steam system disturbances.
- 2 Planning how to react in the near future to predicted changes. For example, electrical load management or gas restrictions.
- 3 Forward planning of production to match operating restrictions with changing sales demands over three to six months.

Achieving the correct standard of economic performance control of a whole chemical complex at levels (1) and (2) has only been possible since the introduction of Super Co-Audinator, and its smaller relations, Auditor and Co-Audinator. Minute-by-minute, the smaller systems combine to pass information up to Super Co-Audinator for use in economic performance control decisions.

In addition, Super Co-Audinator accumulates daily production within the month to date and adds monthly makes within the calendar year to give comparisons with capacity and budget. Average efficiencies are also calculated and compared with budget figures.

One of the most important tasks undertaken for Agricultural Division is management of natural gas use. The Operations Centre divides the total available each day between production units and the target allocation is automatically passed to the Plant Auditors by 6.00 am. In return, Auditor measures the rate of consumption and overall Plant efficiency. If a problem occurs, the Operations Centre is immediately aware of the situation and can reallocate the gas to the Plants which are currently the most efficient, and have spare capacity.

If a restriction on gas occurs, a reduced target allocation is passed by Super Co-Audinator to each Auditor. Then each Auditor will re-calculate and display a new target rate of gas consumption to achieve the revised daily target.

However, the Operations Centre is not just concerned with the natural gas situation. Other site functions monitored and controlled include site steam balance - site liquid Ammonia, site Ammonia gas, hydrogen, etc.

The Centre also provides an improved comprehensive source of data for Agricultural Division's process records which replaces an old manually intensive system. This information, which is continually refreshed, can now be directly accessed (subject to security codes) from any terminal on the ICI corporate network.

The inter-dependence of Plant in sites the size of Billingham brings another set of problems which Super Co-Audinator is now solving. Production levels of individual units cannot be set in isolation; account has to be taken of the prevailing circumstances of surrounding Plants.

The site is subjected to a number of constraints. Typically, these might be such things as natural gas supply, storage capacity, balancing site production of certain chemicals against consumption and sales demands, and steam availability. However, nothing remains constant on a Chemical Plant for long. Consequently, to meet changing conditions like equipment failure or tariff increases on services, there is a need to rapidly find the most profitable way to run the site while satisfying the constraints.

In order to find the most economical operating mode for Billingham under the changing circumstances, a site optimisation package is now in the final stages of development.

The package, designed around a formal mathematical model of the site is scheduled for completion by the end of the year. Its installation will enable users to test the relative economic value of alternative operating strategies.

One of the many consequences of the computer package's introduction will be the ability to charge the cost of services to the Plants at the current value. However, the final aim is to enable each business area to know the instantaneous marginal cost of production in order to assess profitability of additional sales.

As a result of the optimisation package alone, ICI Agricultural Division expects to cut annual costs by several million pounds.

Conclusion

The advanced information system which has been described in this paper has given Agricultural Division the efficiency and flexibility which it needed to stay well ahead in a competitive commercial environment. The system has bridged the gap between Production Plant and the Company Management information system; its success has meant that Auditor systems are spreading rapidly throughout the ICI Group.

TA/84/22 Co-audination - A system bringing real time economic performance control to fertilizer production by J. Springell, ICI PLC, United Kingdom

DISCUSSION: Rapporteurs L.K. RASMUSSEN, Superfos AS, Denmark and B. PERSSON, SUPRA AB, Sweden

Q - Mr. G.H.M. CALIS, UKF, Netherlands

How do you account for product quality in calculating the economic performance of a plant with the Auditor system?

A - Product quality is always an important criterion in the economic assessment of a process. It is more important in some processes than others. One example, important in ammonia production is the hydrogen/nitrogen ratio in the synthesis loop of the process. This ratio has a bearing on the economic performance of the process and we can infer it by using an Auditor to continuously collect a limited amount of process data and to run a theoretical process model which calculates the above ratio and other key operating parameters.

Q - Mr. N.D. WARD, Norsk Hydro Fertilizers Ltd, United Kingdom

The most important element in production costs is raw material cost. Process losses can be accounted for, but there always seems to be losses particularly in solids handling, which cannot be accounted for in this way. Does your system allow for these?

A - Yes, it does help to show where losses occur. As I mentioned earlier, one of the main functions of Auditor is to carry out mass balances and consistency checks. It can be used to calculate the efficiency or losses associated with either individual sections of the plant or the whole process. For example, in NPK production the efficiency of the ammonium nitrate section or that of the whole process can be calculated.

Q - Mr. J.D. CRERAR, Norsk Hydro Fertilizers Ltd, United Kingdom

Computerised optimisation of individual plants is achievable with some effort where the chemistry and thermodynamics are well documented and understood. This does not apply to granulation to the same degree as ammonia and nitric acid. Does ICI intend to apply Co-audinator techniques to NPK-plants? if so, how and when?

A - In answer to the second part of the question - yes, we are applying Auditor to NPK plants right now. It is obviously easier on large continuous single stream processes to exploit the power of Auditor but we are now extending it to other processes. One of the main functions of the system is to allow coordination of each individual plant into the entire production strategy for the complex as a whole.

Q - ICI Divisional Co-audination seems based on the human shift managers. How good are their decisions for action to deal with sudden problems such as breakdown, lack of transport, full storage etc...?