

SOME NOTES ON AUTOMATIC CONTROL IN SOUTH AFRICAN SUGAR FACTORIES

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A comparison between the plants of some vital South African industries such as Sugar Industry, the Iron and Steel Industry, the Chemical, Pulp and Paper Industries as well as Power Stations will single out the South African Sugar Factories for one very noticeable item: The absence of supervising and controlling instruments for the manufacturing process and for a number of ancillary processes. By stating this, I want to exclude the power-generating plant such as the Boiler House and electric generators which are almost automatically fitted with a number of essential instruments.

The almost complete absence of equipment continually supervising and controlling the processing of sugar is astounding for several reasons: However complex this process may be, it can be reduced to some comparatively simple measurements and manipulations which vary for a number of reasons in degree but not in principle. I shall analyze these measurements and manipulations at a later stage.

In the meantime, let me try to assess the reasons for the comparative lack of instrumentation:

One school of thought claims: "Why should we instal expensive equipment such as instruments and automatic controllers? We have trained staff who do their supervisory work well, who produce fair results in our factory and whom we cannot replace by instruments or machines in any case."

Although extensive experience from all quarters of the processing industry is available, it is often considered unnecessary, too expensive and inconvenient to exploit the experience of others for their own factory.

A very important factor, especially in the South African Sugar Industry is that sugar has been produced quite profitably without any of the modern means of supervising the production process.

It has frequently been argued that instrumentation must pay for itself and prove its value not by improving manufacturing methods but by cutting losses. Whereas it can safely be said that losses will be cut by suitable supervision and control, it must, at the same time, be understood that these very losses will become apparent only after instruments have been installed and that they can only be eliminated after they have been determined.

I would like to quote Llewellyn Young from an article in the South African Electrical Review: 3:

"Building up an automatic control system involves the selection and arrangement of the proper controllers, relays, regulating units and selector stations, and their application in such a manner that the theoretical and practical requirements are properly met. Careful study of the proposed plant and collaboration with its designers are therefore necessary. At this stage, the economic aspect cannot fail to assume great importance. If safety of operation is a consideration, as in feed water control, no necessary expense should be spared. If, however, efficiency is the only factor, the extent to which automatic control can be applied is limited by the expected savings and the number of years of improved operation which will ensure repayment of capital, interest, and maintenance costs. The accurate determination of improvement in efficiency is a difficult and costly matter even in an operating station; it becomes almost impossible in the design stage to foretell what results will be obtained and assumptions must of necessity be made, giving rise to more or less intelligent guess-work.

Therefore, although technical appreciation of the advantages of automatic control is simple, factual evidence of improvement in efficiency is scarce owing to the difficulties involved in conducting comparative experiments over long periods of time."

A further reason may be found in the fact that plant and machinery are often very old. The opinion is held that they do not lend themselves to modern ways and means of production supervision.

This is partly true but if one considers the large amount of capital spent every year for modifications of and additions to plant, one is inclined to think that ways and means could have been devised in our instrument-minded age to also provide, without extra cost, for such alterations as instrumentation and automatic control may necessitate.

A striking example may prove this statement. By courtesy of Messrs. Illovo Sugar Estates Ltd. a series of experiments and investigations were conducted. They were to establish that a certain correlation exists between the position of a slide damper controlling the amount of sulphur dioxide

to the sulphitation tower and the resulting pH-value of the juice leaving this tower. The general principle of the experimental arrangement is shown Fig. 2. By gradually opening the damper inch by inch it was expected that a gradual increase of sulphur dioxide to the sulphitation tower would ensue and that, subsequently, the pH-value would be influenced in a way that was predicted by theoretical considerations. A table giving the result of this experiment is shown in Fig. 2.

Slide Position	Draught	pH Liming Tank	mgrs per litre	pH ex. Tower
Closed	0.00	10.7	670	10.20
1" open	0.15	10.7	2130	6.50
2" open	0.40	10.7	2380	6.25
3" open	0.50	10.7	2240	6.20
4" open	0.45	10.7	2000	6.95
5" open	0.45	10.7	1980	7.40
6" open	0.55	10.7	2150	6.70
7" open	0.60	10.7	1790	7.00
8" open	0.45	10.7	1800	7.90
9" open	0.45	10.7	1220	9.40
10" open	0.45	10.7	2100	7.90
11" open	0.45	10.7	1740	8.30
12" open	0.50	10.7	1880	6.60
Fully Open	0.45	10.7	1700	7.90

TABLE 1.

It reveals a very startling fact:

When the damper is withdrawn by only one inch of the full pipe diameter of 12 in., i.e. if only 1/27th part of the area of the pipe is available for the SO₂ flow, the full amount of gas produced in the SO₂ generator is already passing into the sulphur tower. A further opening of the damper does not change the pH-value materially. The fluctuations which occur are due to changes in the gas quality which is indicated by the figures in column 4, Table 1. It is quite obvious that nobody would conceive the idea that only about one inch in the almost closed position of the damper-slide must be used to control the pH-value. Let me assume that somebody installed an automatic regulator, utilising this damper as a control organ. It would prove a complete failure, and there is little doubt that the controller would be blamed for this failure. But there is even less doubt, in my mind, that the plant described can be altered with very small means to make a controller a success and a paying proposition.

From the few figures available from this one experiment, I am inclined to conclude:

(1) A 12 in. pipe from the sulphur burner to the tower with a 12 in. damper and the costly operating gear for such a damper are by far

over-dimensioned. For the amount of SO₂ generated, a pipe diameter of 2½ in. would be sufficient. Instead of an expensive slide, a small butterfly damper would be quite adequate to control the sulphur dioxide flowing to the tower,

- (2) Provided that further tests establish that the sulphur burner itself is adequately dimensioned to supply sufficient SO₂ to meet sulphitation requirements, and that the efficiency of the tower is good enough to absorb this sulphur dioxide, it appears that the draught through sulphur burner and tower must be considerably increased to produce more gas.
- (3) The fluctuations in the "mg/litre" column seem to indicate that the burning rate in the sulphur burner is not constant. In spite of a fairly even draught, it varies quite rapidly. It is obvious that a constant pH-value of the juice from the tower cannot be obtained under these conditions if the damper is set at a fixed position over long periods—a constant pH-index ex tower is only possible by continual adjustments of the slide position which should, of course, be left to an automatic device.

The opinion is often heard that nobody will look at instruments and heed their indications, once they are installed. That is very often the case, because an operator who has to watch a great number of instruments, perhaps even of different types with different scales and measuring in different units, cannot be expected to react promptly to their indications. The logical development was, therefore, to equip these instruments with gear which would automatically react, without the intervention of the operator. He would, then, be free to observe the few remaining and vital instruments.

I do agree that it will require some re-adjustment of mental attitude towards automatic controllers and to our conception of them. We must not see them as technical contraptions which can do miracles, but we must learn to see them as organic parts of valves, juice pumps and plant components which influence a process. That they are—today—separate units, has its explanation in the fact that they have been perfected much later than valves, pumps and other machine parts and that the technique of measuring and controlling has been developed only when it was necessary to improve on the performance of the original plant.

I would like to remind you that the automatic speed control of a steam engine by a centrifugal regulator, the automatic maintenance of a constant fuel: air ratio, or the automatic adjustment of the ignition in a modern automobile engine are also controllers. We do not notice them any more because they are merged with the steam engine and the car-motor. They form an integral part of

them, as one day an automatic pH-controller will form an integral part of the milk-of-lime valve or of the sulphur-dioxide or carbon-dioxide dampers.

One cannot expect and I do not consider it necessary that every sugar engineer should learn to design and understand fully the workings of an automatic controller. It is quite sufficient for him to accept it as part of his plant which has to fulfil very definite functions. One of them is to measure continuously what would have been measured sporadically before, and the other one is to convert the measuring results into proportional forces. They will operate control organs which, in turn, influence plant conditions in such a way that they conform with the requirements. These two functions are in brief the object of automatic controllers, and the fact that controllers and instruments very often occupy prominent positions, in a clean and well illuminated space, stealing the show and diverting attention from the plant, should not confuse this issue.

The fact that an automatic gear can measure and control continuously and tirelessly for 24 hours a day whereas a human operator will soon relax and fall off in the accuracy of his reactions, makes the controller superior to the operator. We must, however, beware of slogans, such as "The Automatic Sugar Factory" with pictures of operators in white coats, in factories and boiler houses meticulously clean and spotless. They have rather distorted the issue: the task is not to introduce robots which would run the factory but to install certain gear which can do automatically and unfailingly certain pre-determined operations which will repeat themselves time and again. The human intelligence is not made superfluous by introducing automatic equipment, but it is given the opportunity to assert itself more efficiently.

How futile it would be to hope that anybody engaged in manually regulating the correct ratio juice : milk-of-lime could detect any such delicate third influence as for instance changes of the pH-value of the initial juice! And how easily this could be done if the fluctuation in quantity would be accounted for by an automatic control, and if the operator would be free to observe and assess the much slower fluctuation of the initial pH-value and allow for it by very slow and minute adjustment in the rate of flow of milk-of-lime! Experience proves that, by eliminating such variables which would "draw" other components in a fixed ratio, much higher degrees of efficiency can be achieved permanently than was ever thought possible for an individual plant.

One consideration that frequently prevented even progressive managements from installing adequate supervising and control equipment is the com-

paratively high initial cost. The price of the individual instrument has become relatively lower over the last 20 years, but very often those alterations to plant, necessary to make new instruments and control equipment adaptable, are requiring large sums of money. This fact cannot be disputed away but it should be understood, on the other hand, that any such alterations plus instrumentation are enhancing the value of the plant much more than the capital expenditure would indicate.

This statement should not lead one to believe that instruments and automatic control equipment can make a new machine out of an old one. It will require very careful investigation into the possibilities of the machine, plant or section of a plant, where such installations are contemplated and any decision to purchase expensive equipment should be subject to a critical analysis. More harm than good has been done by irresponsible instrument manufacturers and dealers by pretending that instruments can do miracles to plant. It must be perfectly understood that instruments and control equipment are supplementary to the plant, and that they cannot do more than help to exploit the plant to full capacity.

It is difficult for me to describe in detail the instrumentation for a sugar factory working under South African conditions because no exemplary factory exists. It can safely be said, however, that it will not differ widely from those instrumentations applied elsewhere. Let me summarise the problems that will occur:

- (1) Two or more components have to be mixed in such a way that a certain result is obtained. The result in this case may be a pH-value which will have to be kept at a certain figure. What does this entail?
 - (a) It necessitates the measuring of the quantities of the various components which have to be mixed. They can be liquids of higher or lesser viscosity, or gases. The normal way of measuring liquids or gases is by means of orifice or similar primary elements built into the pipes which carry them. The design and material of these orifice plates depend on operating conditions. The rate of flow of the various media is normally controlled by valves, slides or butterfly dampers.
 - (b) The pH-value and its fluctuations due to corrective movements of valves, slides or butterfly dampers has to be measured. This is usually done by means of a method yielding an electric potential which is indicative for the pH-value. Various media can impede the accuracy of this measuring principle by depositing chemical reagents on the electrodes.

The entailing inaccuracies of controllers connected to such electrodes are not due to the controller but to the electrodes. It will be the object of some detailed research to prevent or overcome such deposits of foreign matter.

- (2) Temperatures have to be kept at certain levels. This is done by first measuring the temperature and then by correcting control organs which improve or reduce the effect of heaters or coolers, so maintaining a continuous balance between introduced and consumed calories.
- (3) A certain density of a liquid must be achieved by either evaporating water or by adding water. In the first case, the intensity of the evaporator must be regulated by turning on or by shutting off steam valves. In the second case, a smaller or larger amount of water must be added to a liquid, to bring it to a certain Baumé figure. In both cases, the density must be measured by an instrument which is sensitive to specific gravity fluctuations. Its indication must be converted into a proportional force which will operate either steam valve or water tap.
- (4) A steam accumulator should take up excess steam quantities in periods of low steam consumption and should send it back during peak consumption periods. Excess steam makes itself felt by high pressure, steam deficiency by low pressure. A pressure gauge and a converter using its indications to operate suitable valves would constitute an automatic regulator for an accumulator.

Without going into details, I would like to demonstrate with a few examples some of our most common regulator problems:

(5) **Pre-Liming** (Fig. 1)

Problem: A certain amount (Y) of milk-of-lime has to be added to the initial juice to bring it to a desired pH-value.

The quantity (X) of juice varies according to crusher operations;

The initial pH-value (Z) of the juice varies.

Principle of Solution: The quantity "X" of juice is measured by means of a primary element, i.e. an orifice plate. The measuring result will be a differential pressure. The quantity of milk-of-lime "Y" is measured by means of another primary element which is so calculated that it will give for the quantity of milk-of-lime, normally required, the same differential pressure that "X" will produce.

Both impulses are acting through measuring systems "x" and "y" as thrusts Px and Py

on a converter "C". This converter operates a servo-motor coupled with the milk-of-lime valve "V". The servo-motor is so connected to the converter that an increase, for instance, of Px which would indicate an increase of X, would open the valve V and so admit more milk-of-lime.

In case of a change in the initial pH-value of the juice, the pre-determined ratio juice : milk-of-lime would not be correct anymore. The pH-meter would indicate a change and would transmit its indication to the ratio-alternator RA. By moving the contact element F up or down, the ratio alternator will establish a new ratio juice : milk-of-lime by shifting the equilibrium of the two thrusts Px and Py to a lesser quantity of milk-of-lime for a lower initial pH-value, and vice versa.

Sugar technologists may perhaps stumble over the fact that the milk-of-lime is injected directly into the juice main without an intermediate pre-liming vessel. This method is not customary in Natal sugar factories. I would like to point out, however, that the method of admitting milk-of-lime directly will most decidedly ensure a very thorough mixing of the two components. This will in all probability reduce the curing time which was hitherto accepted to be anything from 8 to 20 minutes. An experiment may well prove that curing vessels can be considerably reduced in size if the milk-of-lime were not admitted in an uncontrolled stream direct into a big batch of juice but if it were apportioned by means of an automatic device as suggested in this paper.

This experiment may also prove that the scaling of evaporators will decrease considerably, as in the case of a sugar factory in Germany where it was stated that "errors in pH-value have not occurred any more and faulty operation of the filter plant has been eliminated. This may be proved by the fact that the evaporator has worked uninterruptedly for 12 weeks . . ."

(6) **Sulphitation** (Fig. 2)

Problem: Sulphur-Dioxide should be admitted to a sulphitation tower in such quantities as to give a desired pH-value for the juice at the bottom of the tower.

Principle of Solution: Sulphur-dioxide (1) is drawn into the tower by an induced draft (2). On its way up, it encounters the juice coming from above (3). The rate of absorption determines the pH-value at (4). The impulse from (4) is converted in (5) into a proportional pneumatic pressure which acts on diaphragm (6). The resulting thrust

causes the servo-motor (8) to open or close the butterfly-damper (7) thus admitting more or less sulphur-dioxide to the tower.

- (7) *Problem:* (Fig. 3). The density of milk-of-lime should be kept at a certain Baumé figure which has been found most suitable.

Principle of Solution: Lime is mixed with water to form a liquid which will easily flow but which will have a density considerably higher than that required (1). This liquid will overflow continually into the diluting vessel (2) where the density is measured in (3). The result is transmitted to diaphragm (4) as a pneumatic pressure. The resulting thrust is acting against calibrated spring (5) on hydraulic converter (6). This will operate water valve (7) admitting sufficient water to dilute the effluent from (1) to the desired degree.

Anyone acquainted with measuring principles will notice that I am deliberately simplifying these problems. In their essence, however, these examples are giving a true picture of what automatic controlling in a sugar factory, as in any other factory, really means. Any factory manager or sugar engineer who is approaching the problem of controlling in this straight forward way, should, after a while, be in a position to find applications for effective controllers. That the final control mechanism will, then, incorporate several components which will take care of occurrences and inherent conditions of the plant, which to describe would take us too far here, should not divert from the basic issue that automatic controlling means:

- (1) Measuring and
- (2) Converting measuring results into positioning forces for control organs.

In conclusion, I would say that the striking absence of instruments and controllers in the South African Sugar Industry, compared with their abundance in plants of other industries such as the Iron and Steel Industry, the Chemical Industry, Power Stations, Gas Works, Pulp and Paper Factories, etc., must lead to assume that cogent reasons have prevented their installation. A great number of discussions with managers, chemists and engineers have revealed the following opinions:

- (1) Sugar from South African cane is "difficult" to process, and instruments and controllers are not likely to assist materially.
- (2) An attitude of caution has created the feeling that it would be better to await positive results from other sources rather than to obtain them in their own factory.

- (3) A traditional attitude that sugar has been produced without up-to-date instrumentation for such a long time.

In the face of the obvious advantages of adequate instrumentation and automatic control equipment as they have manifested themselves elsewhere, it appears that the South African Sugar Industry or one of its appointed organisations should create a Study Group of Sugar Technologists, Plant and Instrument Experts who would make it their task to establish the genuine possibilities and the extent to which the South African Sugar Industry could be modernized and made more efficient without major capital expenditure.

Acknowledgments.

I would like to thank those firms and individuals who have willingly put their experience at my disposal and who greatly assisted in compiling this first approach to an important problem. I would specially like to mention The Illovo Sugar Estates Ltd. who have conducted experiments on my behalf and the Sugar Milling Research Institute which has analysed and criticised my suggestions.

REFERENCES.

Automatic Regulators shown in schemes 1, 2 and 3 by ASKANIA.

¹ Young, Llewellyn: The South African Electrical Review.

² Fricke: "Zucker" No. 18, May 1952.

Mr. Dymond said that yesterday they had heard Mr. Barnes talk of the jaggery factories in East Africa. They had now swung to the conception of a factory on modern lines with automatic equipment and regulation. They knew that it was not possible to continue with slap-dash methods, but that some adequate instrumentation had to be introduced in due course.

Mr. Barnes said the author of the paper was to be congratulated on a paper of the greatest interest to every milling officer, whatever his status. One reason for the absence of automatic control in sugar factories has been the availability of labour at reasonable cost. A great deal of the automatic controlling introduced into the Sugar Industry has largely been compelled by shortage of labour. The two instances discussed by Mr. Rohloff were only a few among a great number. Time lost through various causes frequently caused losses in other directions in the factory. Mr. Barnes described a system of automatic control of the cane carrier in relation to the quantity of feed of cane at any one time, to avoid knife chokes. In the system it had been customary for one man to control the feed by means of visual methods. This worked well early in a shift, but later when the man became

tired chokes became frequent. A system of automatic control was introduced by which the carrier was stopped when the current was less than that at which the knife motor would be tripped out by a choke. After a small interval the automatic device allowed the carrier to move very slowly and thus fed the cane very slowly for a short time through the knives and so avoided an overload and a choke. This system had saved many hours which would have been lost by manual control. Mr. Barnes said there were many other instances where automatic devices could be installed to provide greater efficiency and avoid loss of time by comparison with manual operations.

Mr. McCulloch stated he would also like to congratulate Mr. Rohloff on his paper which would be of importance in future developments in the Sugar Industry. Automatic control had been widely adopted in the chemical industries and in oil refinery practice and perhaps had reached a peak of development in the latter. It was now possible to operate the refinery process by a handful of men, instead of a staff of 300—400 required for the same operations done manually. Referring to the diagram of Fig. 1 he said that he thought there would be a probability of the pressure pipes connecting the milk of lime pipe "Y" to the primary element "y" becoming blocked since the contained liquid was sensibly stagnant and protecting devices would have to be fitted. He also referred to the diagram displayed on the blackboard and asked if it would not be preferable to retain the 12 in. bore SO₂ pipe, open the damper a limited extent and instal a small bore pipe in parallel. Control of the SO₂ proportion would be attained only in the latter pipe.

Mr. Rohloff drew attention to the fact that the diagrams in his paper indicated only the principles of control in the various cases that he had cited. He said he knew quite well that the diagrams were over-simplified and required further elaboration in practice. He said that the question of pre-liming was important as in present methods a long time elapsed before there was thorough mixture of lime with the juice, whereas with automatic control this mixing was instantaneous, thus saving again on time and improving on the speed of the process.

Mr. Rault also congratulated Mr. Rohloff on the appropriateness as well as the lucidity of his paper. Mr. Rohloff had indicated in his paper why instrumentation had not been widely introduced in the Sugar Industry. The automatic control of processes by instrument demanded, as a pre-requisite, that

the indications given by such instruments should be true, otherwise automatic control entirely based on their findings would give a false sense of security. His firm had gone to the trouble of putting expensive pH meters at three different stages of the clarification process, as indicators helping the workmen, but not replacing them. He was much in favour of clarification control at the factory itself, by pH meters. He had even praised the work of these instruments at the Technologists' field day held in Mount Edgecombe two years ago, but he was now sorry to admit that they had been of little use to him this season, on account of the lack of a scientific instrument specialist on the maintenance staff of factories, or even in Durban, as the ordinary mechanic or electrician was not trained to do such intricate repair work. It was not surprising that the owners were now somewhat sceptical on the benefit to be derived from these expensive instruments which required additional highly paid staff to keep them in working order.

Mr. Rohloff agreed that an important step had been taken by employing an instrument maker for the Industry. Iscor had installed some 120 automatic control instruments which were today controlling all types of operations at Iscor automatically. He felt that the Sugar Industry was bigger than the iron and steel industry, but at Iscor there was a large team of instrument makers kept busy all the time and Iscor had found that employing these men paid handsomely in that adequate automatic control over all processes was maintained. He felt that the Sugar Industry could adequately employ more than one man.

Dr. Douwes Dekker said that it was not possible to be dogmatic about the necessity of mixing juice and milk-of-lime in the shortest possible time. One of the chemical reactions when juice was limed was the precipitation of calcium phosphate and it was known that time was required to make this precipitation complete. It was probably of advantage to keep the juice alkaline for at least a few minutes.

Mr. Dymond referred to Mr. Rohloff's suggestion that a sub-committee be appointed to go into the question of instrumentation. Mr. Rohloff had opened up a new vista of mechanisation and had indicated the possibilities for the Industry. He felt that here was an important field of research for the Sugar Milling Research Institute or some other body. He asked that a vote of thanks be accorded to Mr. Rohloff.

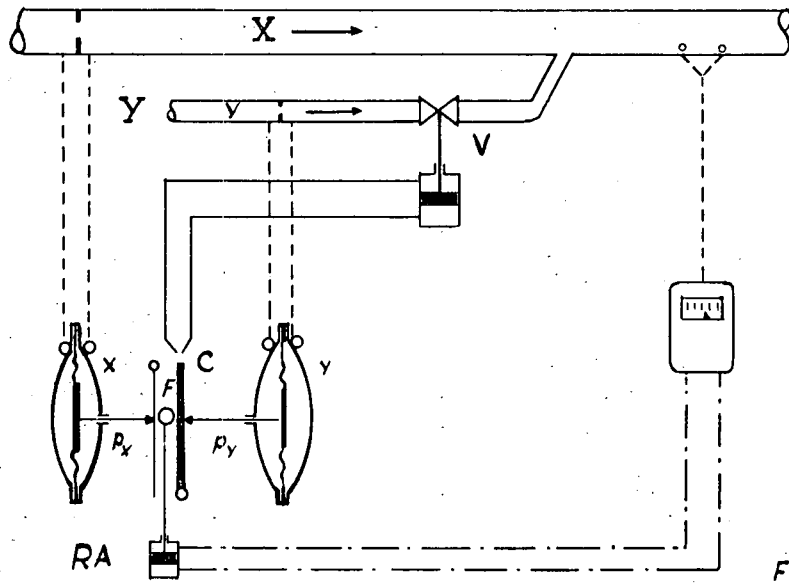


Fig. 1

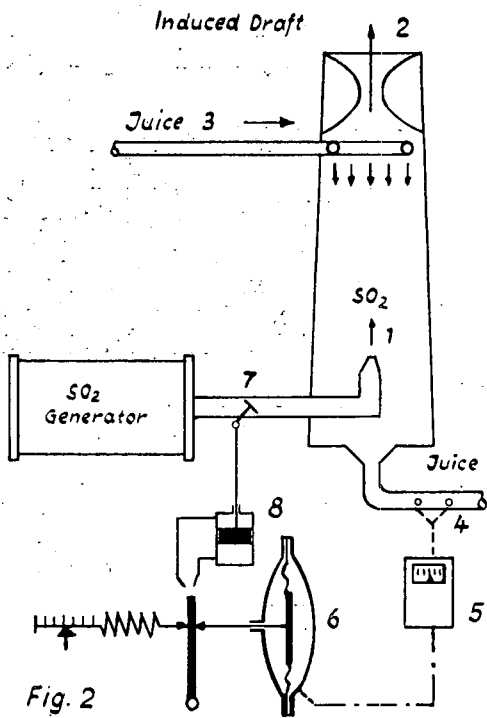


Fig. 2

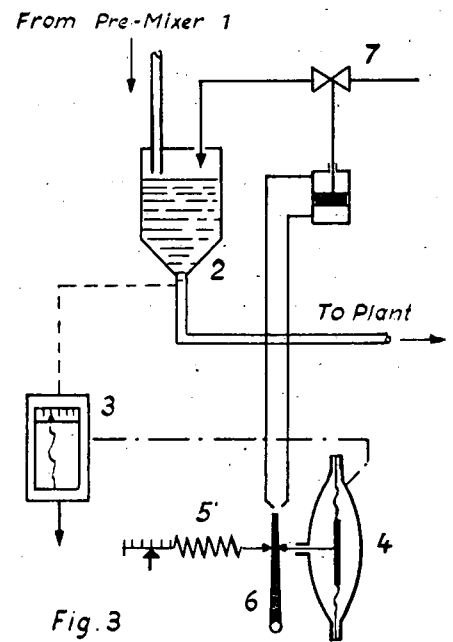


Fig. 3