THE KURUNEGALA FERTILIZER BLEND CONTROLLER SYSTEM

{This is a description of a modification done at the Fertilizer Blending Plant at the Ceylon Tobacco Company }

Carried out by

A.K. Premawardena, J. Abeyratne, B. Wewalaarachchi

Abstract

In the early part of 1991 we handled the replacement of the control system of the fully automated fertilizer blending facility belonging to the Ceylon Tobacco Company. This was a very interesting and challenging project as we had to design and put in place a control system replacing an existing system on which we had no technical information other than a working specification. Therefore we had to handle the system design, PLC and computer programming, installation and commissioning within the resources of the team. The result of our efffort was a very flexible and userfriendly control system. The financial gain of this project was substantial. Herewith we attempt to present this work as a system design and a development of a digital closed loop control system without going into specific details of PLC or computer programming which was felt to be uninteresting to the general engineering fraternity.

Introduction

The fertilizer plant located in Kurunegala blends a wide variety of fertilizer for many different kinds of plantations.

This plant was a completely automated unit which could handle 25 to 30 tonnes of blended/packed fertilizer per hour. The two main components of this plant were

a) Blending unit
b) Packing unit

The Blending Unit consisted of 5 continuous feed arrangements each with a bucket elevator, a hopper bin, and a feeder conveyor. The fertilizer was fed at the input point of the bucket elevators and discharged through the bin over the feeders into a collecting conveyor. It is at the point of the feeder that the actual blend is set by a closed loop speed control system. The material falling onto the collecting conveyor is mixed thoroughly at the mixing cylinder and sent for packing. The packing machine is also an automated unit which seals and packs 50 kgs. of fertilizer in bags.(ref. Figure 1')

The blending unit is the main component of this plant. This consists of 5 hopper · feeder arrangements which discharge material into 5 continuously running conveyors mounted on weigh decks and the speeds of these units were controlled so as to give a set discharge over a given time using a thyristor controller connected to a separate motor. The control loop operation was handled by 5 separate micro computers (Congrav "c").

The blending operation was controlled by 5 separate Congrav "c" micro controllers and a group controller. The group controller was a dummy unit which gives throughout information to each Congrav "c". The Congrav "c" was an Z80 based Eprom controlled intelligent controller which handled all control and calibration operations of each feeder. The controller possessed an alfanumeric key board which was used to input calibration information and also issue commands. The 7 segment LED display was used to display operating parameters. Since a fair number of operations had to be handled by this method the system

Mr. A.K. Premawardena, BSc(Eng)Hons 2nd Class Upper Division (1986) from the University of Peradeniya in Electrical and Electronics Engineering, is presently employed as Engineer Projects, Ceylon Tobacco Company, Kandy.

Mr. J. Abeyratne, BSc(Eng)Hons (1986) from the University of Peradeniya in Production Engineering, is presently employed as an Engineer at Hayleys Limited (Dipped Products).

Mr. B. Wewalaarachchi, BSc(Eng)Hons 2nd Class Lower Division (1987) from the University of Peradeniya in Electrical and Electronics Engineering, is presently employed as a consultant in Data Processing attached to the International Labour Organisation (and ICTAD, Sri Lanka).

operation was not very user friendly and the operator had to be trained specially for this purpose.

The Problem

The Congrav "c" controllers which were used in process were of German origin and were about 7-8 years old. The cost of a single unit from the original suppliers came to about Rs. 1.5 million. It is possible that this high cost was a result of this Z80 based control unit being out of production and replaced by more modern units. It was also impossible to repair these units as all the PCBs used were three layer units and no circuit diagrams were made available by the supplier.

A set of 5 controllers were required at the time this project was envisaged to replace the faulty controllers and to maintain a sufficient level of spares availability. This would have cost Rs. 7.5 million on spares alone. A completely new system would have cost approximately Rs. 11 million.

The Objective

With the rapid development of the control industry it was inconceivable why each feeder had to be handled by a separate microcontroller. With the presently available technology it was possible for one central processing unit to handle all five control operations and still have time to spare for other utility operations such as totalisation etc.

A particularly suitable P L C was found for the replacement of the control system and the estimated cost of the project was approximately Rs. 800,000 which was about 10% the cost of any other option.

A technical description of the earlier control system

(Ref. Figure 1)

The hard ware items involved in the control system were

1) Group controller
2) Congrav "c" microcontroller
3) Precision Load Cell
4) Amplification board
5) Thyristor controller AX 108
6) DC separately excited motor with tachogenerator

The group controller was a dummy unit which controlled the overall throput. The set throput value was converted to an analog voltage and given to each Congrav "c" as an input. The percentage could be set on each controller. The value of the group controller input and the set percentage would set the discharge set point for each feeder.

Using this set point and taking the load cell reading as a variable input the speed of the feeder conveyor was calculated within the microcomputer. This value was the output to the thyristor controller which governed the speed of the motor drive.

A closed loop speed control system continuously monitored and corrected the actual speed of the DC motor.

In addition to the main control operation described above other calibration operations were also handled by this unit (thyristor calibration, adaption factors, material calibration).

Replacement System

(Ref. Figure 2)

As in the diagram the computer and the PLC were connected thro the host link adapter and all five feeders were linked to the PLC. The computer was used to do the function of a broad based group controller.

The Omron C200 H PLC was selected due to its modular nature. One of the advantages of this unit above other contemporary units was that, due to its modularity a system could be set up with nearly no redundancy of input output channels.

Equipment used:

1) C200 H Modular programmable logic controller with

   a) CPU
   b) A\D D\A converters
   c) Logical input output units
   d) Host link adaptor for communication with the computer

Why use a computer?

An IBM PC was selected over a 7 segment display or an ASCII key board due to

1) Economy on I/O channels
2) Improved flexibility
3) Use for data acquisition and report generation

i.e. The computer was used to

a. set blends
b. set throput
c. monitoring of the totaliser
d. monitoring of the flags
e. setting of blends/are defining blends
f. set operating modes and change modes

Programming - General

The input data of the load cell reading and tachogenerator voltage were read through scaled A\D inputs of the PLC and were stored in data memory areas. In addition to this the other system constants were sent to the PLC at the beginning of each operation and stored in data memory areas. These were stored in Binary Coded Decimal form as in this way handling the calculations was simpler rather than using hexadecimal or binary modes. In the interests of the accuracy and the clarity of handling varied operations the system constants were sent at the onset of each new blend from the computer. All calculations were handled by the PLC and their results were stored in the computer. This was in the interests of optimizing accuracy of calculations as well as improving the flexibility of the user interface. Handling ongoing calculations in the computer would impose severe restrictions on the accuracy of the computer at 9600 baud. It would also reduce the flexibility of the computer program by locking it out on a nonproductive calculation.

By making the start stop intervals and hold times user defined the system has been given the flexibility of accommodating future mechanical changes but the system was given adequate protection against tampering by giving different password levels to limit access. Also the main menu selections and access has been made operation dependent so that no damage can be done to the system by wrong selections.

The modes of operation could only be thro the computer. For the system to start operating in any mode other than Tare the "start" flag should be on. This can be set either from the computer or by pressing the start button on the panel. Likewise the system can be stopped by terminating the start request from the computer or pressing the stop button. In the run mode the start flag is set up as a request for sequential start and the stop as a sequential stop.

A description of the modes is given below.

The operating modes

Since one CPU was used to handle all operations of the system were set up by clearly defined modes of operation. Also a level of priority was set on these modes to avoid clashing of operations. The modes of operation were as follows.

Tare

This operation was meant to offset all static and dynamic stresses of the system. The feeder was cleared of all material and run at 50% full speed. The load cell reading at this point was taken into the PLC and stored as the tare value to be used in other calculations.

Thyristor Unit Calibration

In this operation proportional voltages were set by the PLC output to the thyristor controller and the potentiometers on the thyristor controller were set to modify the behaviour of the controller. This was done so as to ensure linearity of speed response over the operating voltage range.

Material Calibration Mode

This is the mode which most closely resembles the actual control operation. Here the blends/Throputs are set and the feeders are discharged for a set time to measure the quantity.

The ratio of $\dfrac{\text{actual quantity}}{\text{expected quantity}}$ up dates the computer/PLC with a new weigh bridge length. This constant is incorporated into the system to compensate for minor electrical and mechanical drifts of the system.

In harsh corrosive environments such as in a fertilizer factory control factors do not remain constant due to corrosion, wear and tare and electronic drift. Therefore it is imperative that this operation is done at least fortnightly.

The Run Mode

<u>The Feed Back Control System</u>

The set point information is taken from the computer. The value of (set % *Total throput) is sent to the PLC.

Using the equation of

$$\text{SET POINT} = \frac{\text{Belt load} * \text{Calculated speed} * \text{BSF}}{\text{W B L}}$$

BSF (Belt Speed Factor) :- used to convert r p m to m/s belt movement.

WBL (Weigh Bridge Length) :- to convert load cell reading (Kg) Belt load (kg/m)

(Ref. Diagrams 3 and 4)

The above calculation is done every 700 ms and the actual motor speed is kept as close as possible to the calculated motor speed using the feedback loop given in the above diagrams.

The variables of this equation are (Ref Figure 4)

a) Calculated speed - speed is calculated using the set equation
b) Actual speed - (tacho speed) - actual speeds are read from the tacho generator.
c) Error in speed - (a-b) or (b-a) depending on the result of comparison (a/b)
d) Correction - (e/2) or + (e/2)
e) Compensated speed this is the actual speedout put to the motor controller.
f) All these speed calculations are done using BCD functions.

but output can be only in binary format. Therefore the BCD values had to be converted to binary.

Also if the calculated speeds are higher or lower than the upper and lower bounds of speeds the calculations are limited at 3000 rpm & o rpm;

Response of the Control System

A few tests were carried out to test the response of the control system when it was operating in the closed loop mode. It was noticed that the response of the operating system depended on two factors. They were the **feedback error factor** and the **timing of the calculations**. With a view to optimize the operation it was decided to check the response to the change of one factor while keeping the other constant.

Case I :- Vary the error factor keeping the timing fixed

(Ref. Figure 4)

Different error factors were tried out to attain stability. The speed variation was monitored on the computer. The system was started from zero speed and a constant set speed was achieved by hanging a constant weight on the load cell. The weight used was 3 Kgs.

The error factors tried out were e, e/2, e/4

When the error factor of e was used as the feedback variable the system was unstable. The speed started oscillating and stability was not achieved in a reasonable time period. It was found that when the error factor of e/2 was fed back the system responded quickly with the minimum amount of oscillation. The error factor of e/4 made the operation very sluggish, therefore an error factor of e/2 was chosen. (ref response diagrams below).

Case 2 :- Error factor constant, data intake interval variable

One noticeable thing in this control system was that the data intake time interval played a very important part in the stability of the control system. In the case of this PLC the set of programming instructions took a specific time interval to execute. This is referred to as the scan time of the PLC. It was during this time that all the control calculations took place. Since the program contained many complicated calculations the program scan time was substantial. It was noticed that when the program scan time was close to the data intake time interval the system was oscillating before reaching stability. The data intake interval of 700 ms gave the maximum stability. The average scan time of the program loop was roughly 50 ms and the actual time taken to perform the calculation was only about 2 ms.

Operational limits

To maintain blend accuracies it is imperative that the operation of the control hardware such as thyristor controllers and load cell amplifiers are operating within the linear range. To allow for this the limits of speed and load cell reading are set within the computer. These have been allowed to be defined by the user.

In addition due to the extreme sensitivity of control system the calculated speed may reach these limits instantaneously. These conditions are allowed to prevail for a user defined hold time. These could stabilise and ensure normal operations subsequently. Therefore a time before this abnormality and emergency alarm condition is given.

Software Program

Objective

The main objectives of designing the program are as given below.

1. To define the system parameters in a user friendly and simple manner whenever necessary.
2. To monitor the system.
3. To keep a record of the system behaviour.

Apparatus used

1. IBM PC\AT
2. Host link unit (RS 232 Compatible) for the programmable logic controller.

Goals

The following tasks had to be accomplished at the first stage of the design.

1) Select a programming language with the following features.

a) should support serial port communications, read and write from the port.
b) should be fast enough to process inflowing data while reading and writing from port.
c) should contain routines to maintain a database.
d) should be a compiler so as to maximise the working memory and to use the overlaying technique to load program part by part to RAM.
e) should contain routines to build a friendly user interface.
f) should allow to prepare user defined run time error handling procedures as the system is controlling a real time job it should not be stand still under any circumstances.

Language Clipper 87 was selected due to features c and f and the ability to create libraries with "C" language, Microsoft "C" Ver 5.0 was selected to develop the communications unit and a support library to patch the system where speed was critical.

2) In designing a communication protocol for the PLCIBM Pc communication the main factor which had to be taken into account was that the PLC could not issue commands to the computer. Therefore the command routines had to be handled by the computer. The following tasks had to be handled by the Pc

1. Read and modify Data Memory areas of the PLC when necessary to alter system parameters.
2. Change Data Memories to indicate commands.
3. Monitor read flags continuously to identify present status and take necessary action.

3) In the case of monitoring a large quantity of data had to be faithfully retrieved in a limited time.

Therefore every read and write error status of the PLC is checked before processing the next request.

4) The PLC takes sometime to process the requests from the computer due to the mechanical intertia of the system. In this case the computer had to follow the PLC. On the other hand if a request is invalid the present status has to be removed from the system.

To overcome this problem a special handshake was devised: for every request from the computer the PLC alters the status of an internal flag as an acknowledgement of processing the command. The computer changes its status after the flag change in the PLC. If the PLC does not respond after a given time the computer withdraws its request and treats it as an ignored request.

Totalization

The totalization was done within the PLC so as to improve the accuracy of the system. In addition this also enables the operator to handle other functions which are available with the computer such as user defined reports. This is no hindrance to the system as when each new blend is set the totaliser values are read by the computer from the data memories and stored in the data base.

The curve of (belt Ld * actual speed) is integrated and multiplied by the system constants to set totaliser values for each conveyor.

These are added up to set total value on the monitoring screen and the values are given as percentages of the total so as to enable the operator to monitor blend settings accurately.

Discussion\Conclusions

A large number of multiply long or divide long operations were used in the calculation. These calculations were time intensive. Therefore to reduce scan time the program was overlayed using a sequential rotating bit for each feeder. Since the overlaying time interval was much less than the data intake interval the system accuracy was unimpaired.

Even though the manual stated that C200H maximum scan time could be changed we couldn't increase the maximum scan time limit by changing the watch dog timer.

Due to the fact that the programs were done locally a large cost saving was achieved and a very flexible userfriendly system was developed.

Finally we should voice our heartfelt gratitude to Mr L.C.R. de Silva (Technical Planning and Development Manager) and Mr. M.C. Bahardeen (Leaf Processing Manager) both of Ceylon Tobacco Company Limited without whose support, help and encouragement this project would not have been a reality.

Appendix

1) Congrav "c" - An Z80 based weigh feed controller
2) HR - Holding relay of the plc
3) DM - Data memory area of plc
4) COMP - The numeric comparison function of plc
5) BIN _ BCD to Binary conversion
6) MOV - Movement from one DM to another DM\Output etc
7) PLC - Programmable logic controller

Fertilizer Plant Layout Diagram

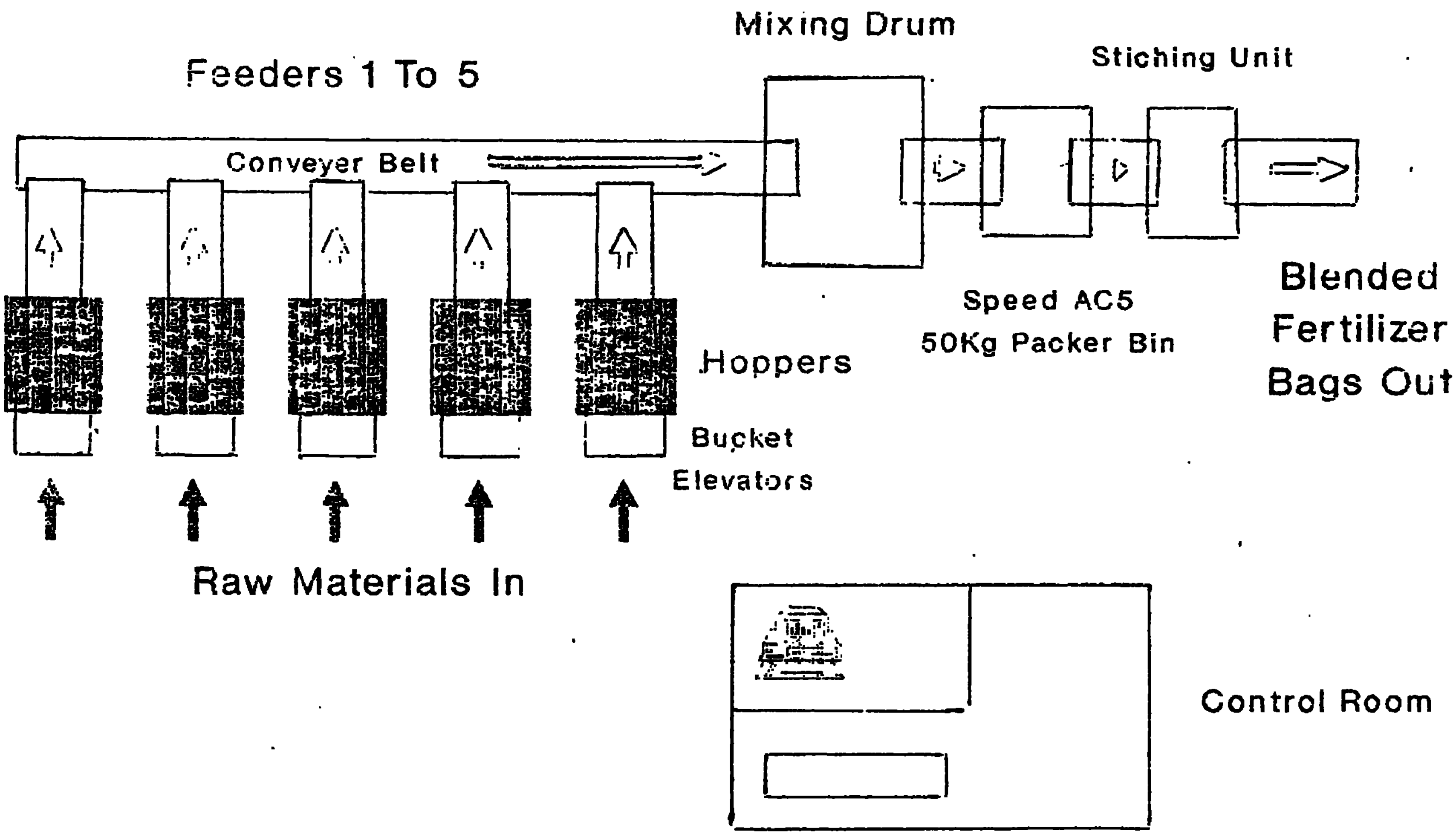

Figure 1'

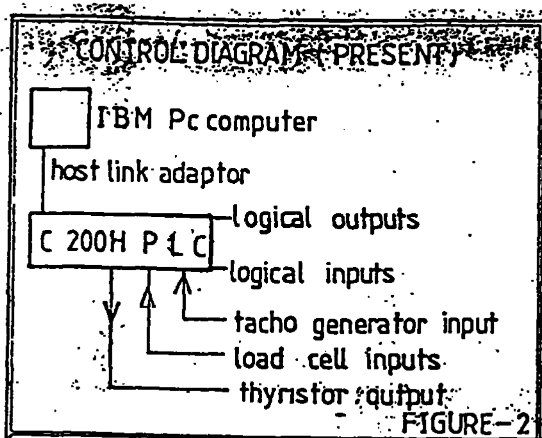

FIGURE-2

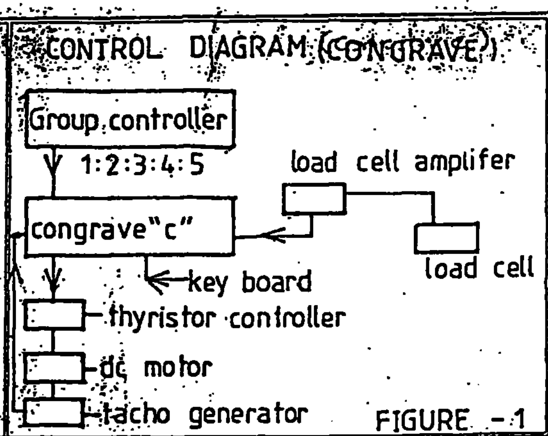

FIGURE -1

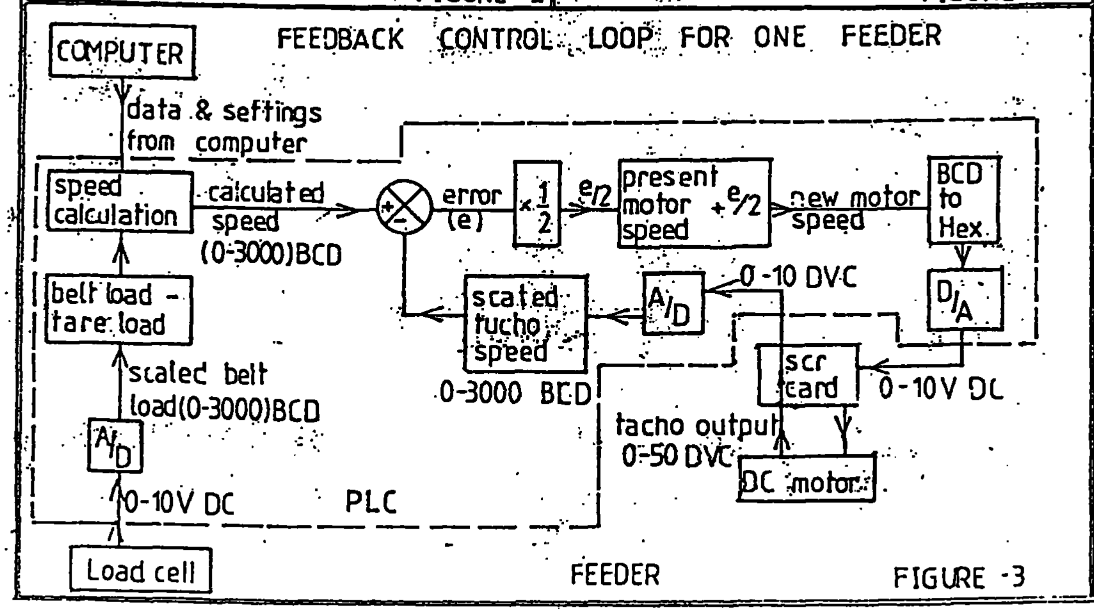

FIGURE -3

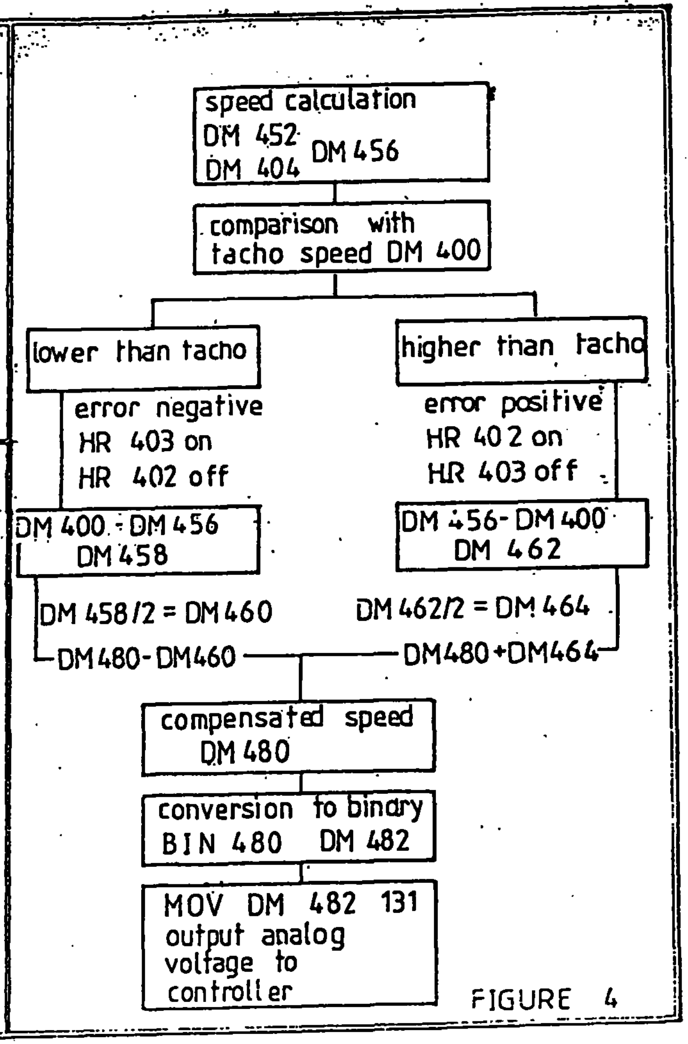

FIGURE 4