DESIGN AND DEVELOPMENT OF PLC BASED CONTROL SYSTEM AND PC BASED OPERATOR INTERFACE FOR 2000 T HYDRAULIC PRESS AND ITS AUTO DOSING SYSTEM

A DISSERTATION

Submitted in partial fulfillment of the

requirement for the award of the degree

of

MASTER OF TECHNOLOGY

in

ELECTRICAL ENGINEERING

(with specialization in Measurement and Instrumentation)

By

MANJUL SHARMA

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

ROORKEE-247 667 (INDIA)

APRIL, 2006

ID No. MT 306/2006-1/MS-VK-SM

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation entitled **"DESIGN AND DEVELOPMENT OF PLC BASED CONTROL SYSTEM AND PC BASED OPERATOR INTERFACE FOR 2000T HYDRAULIC PRESS AND ITS AUTO DOSING SYSTEM"** submitted in partial fulfillment of the requirement for the award of degree of Master of Technology in Electrical Engineering with specialization in Measurement and Instrumentation, in the Department of Electrical Engineering, Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out from March 2005 to August 2005 at Nuclear Fuel Complex, Hyderabad under the guidance of Shri B. Satyadev, Scientific Officer, Nuclear Fuel Complex, Hyderabad, Dr. S. Mukherjee, Professor, Indian Institute of Technology Roorkee, Roorkee and Dr. Vinod Kumar, Professor, Indian Institute of Technology Roorkee, Roorkee. The matter embodied in this dissertation has been submitted by me as a project report in Nuclear Fuel Complex, Hyderabad.

April 2006

Place: Roorkee

(Manjul Sharma)

CERTIFICATE

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

(Dr. S. Mukherjee)
Professor,
Department of Electrical Engineering,
Indian Institute of Technology Roorkee,
Roorkee-247667
India

(Dr. Vinod Kumar)
Professor,
Department of Electrical Engineering,
Indian Institute of Technology Roorkee,
Roorkee-247667
India

(Shri B. Satyadev)
Dy. Mgr. (IMS, OP)
Nuclear Fuel Complex,
Hyderabad, India

B. SATYADEV
Dy. MANAGER
GOVT OF INDIA; D. A. E.
NUCLEAR FUEL COMPLEX,
HYDERABAD - 500 062.

ACKNOWLEDGEMENTS

I wish my regards to my guide Shri. B.Satyadev, SO/F, Instrument Maintenance Section, NUCLEAR FUEL COMPLEX for his cooperation and guidance.

I would also like to thank to my guides Dr. S. Mukherjee, Professor, Department of Electrical Engineering, Indian Institute of Technology Roorkee, Roorkee and Dr. Vinod Kumar, Professor, Department of Electrical Engineering, Indian Institute of Technology Roorkee, Roorkee for their encouragement and motivation to complete this dissertation.

I convey my wholehearted thanks to Shri. D.Vasudev Rao, SO/SB, IMS for his knowledgeable guidance in PLC programming and encouragement at each step.

I would also like to thank the IMS lab staff, Nuclear Fuel Complex, Hyderabad for thier helpful hand in the completion of this dissertation.

I would also like to thank to my family members for their constant support and my friends Mr. Deepak Rajpurohit (R/S Biotechnology,IIT Roorkee), Mr. T. T. Srichandan and Mr. Mayank Desai and other friends at NFC, Hyderabad for supporting and helping me during the period of dissertation.

MANJUL SHARMA

ABSTRACT

A hydraulic press is utilized to make different Zircaloy compacts by adding alloying elements to Zirconium sponge on-line. The press is equipped with automatic weighing and dosing system to dispense Zirconium sponge and alloys into press die-cavity. The alloys are sandwiched between the layers of Zirconium sponge in a predetermined pattern.

This dissertation aims at:

1) Development of application program for Programmable Logic Controller (PLC) to control press operations and on-line weighing and dispensing the different materials into die-cavity. PLC receives various set points from PC based Human Machine Interface (HMI) and sends the actual values for operator information, logging and alarm generation. PLC also sends the data to mimic status of various sub-systems.
2) Development of PC based operator interface using CIMPLICITY HMI package for computation of composition of alloying elements in weight percentage of compact, based on chemical analysis of sponge. PC communicates with PLC over serial interface.

LIST OF ABBRIVIATIONS

PB	Push Button
PLC	Programmable Logic Controller
PC	Personal Computer
LS	Limit Switch
PS	Pressure Switch
I/O	Input/Output

LIST OF FIGURES

LIST OF TABLES

CONTENTS

The 2000 Ton hydraulic press plays a vital role in manufacturing the alloys of zirconium from zirconium sponge. There are different alloys of zirconium used in the nuclear [5] applications, mainly zicalloy-2, zircalloy-4, zirc-niobium2.5%, and zirc-niobium1% prepared in Nuclear Fuel Complex (NFC). The New Melt Shop is one of the units of NFC where zirconium comes in the form of sponge in lots from Zirconium Sponge Plant and it is converted into alloys. The main units of the New Melt Shop are 2000 Ton hydraulic press, Electron Beam Welding (EBW) Machine and Vacuum Arc Remelting (VAR) Furnace.

The zirconium, which is a basic component for alloy, comes to hydraulic press in form of sponge. The press is used to make compacts of the zirconium sponge and alloy elements, and then the compacts are welded in the EBW machine to make consumable electrodes for the VAR furnace. The product comes out of the VAR in the form of ingots which is then transferred to the fabrication plant for making the cladding material of nuclear fuel pallets. The alloy elements are mainly tin, niobium, chromium, iron and nickel. An Auto Dosing System (ADS) does the weighing and dispensing of the alloy elements to the press. The ADS is an assembly of number of storage bins and weighing mechanism for zirconium sponge and alloy elements.

To control the operations and sequences of the press and the ADS a PLC (Programmable Logic Controller) is required which can handle the large number of inputs and outputs generated in the process, they may be digital as well as analog. To control the whole system a PLC is installed with an operator interface unit as a PC. In the existing scenario the ADS is not functioning and only the press is controlled by an old PLC in semi automatic mode and the dosing to the die cavity of the press is being done manually. The compacts of alloys earlier produced in 2-layer sandwiching pattern, now being produced in 3-layer sandwiching pattern.

Auto dosing system (ADS) is a generic term and it can be used for any system which is used for feeding of raw materials into the final manufacturing process and does not have any manual intervention. The ADS has been proved to be a very useful part in many systems but being an addition to the system cost it can only be applied for those systems in which the following factors are to looked into:

- Fast and effective working
- Accuracy of the quantity of raw materials
- Safety of the workers (for example in nuclear industry)
- Hygiene (for example in pharmaceutical industry)
- Fully Integrated Production Unit.

The ADS used in this dissertation work is for the automatic dosing of the alloys components for the formation of alloy, which is described in the next topic. The other dosing systems are

- Chemical Auto Dosing System [7]
- Dosing system in Food and Beverages Industries.
- Automated Production Line [8]
- Automatic Dosing Machine for Priming Compositions [9]

1.1. AUTOMATION POLICY [9]

During the design of any automatic system for a process the designer has to follow some strict logics in his/her preliminary approach

- He/she must be familiar with the process.
- He/she must anticipate causes and effects
- He/she must restrict risk factors
- Accessibility
- Integration of 100% inspection in line

1.1.1. SIMPLIFICATION OF THE PROCESS

- Reducing the number of operations;
- Using standardized equipment;
- Appropriate design of special equipment.

1.1.2. LOW CONVERSION COSTS

- Flexible equipment;
- Adaptable equipment.

1.1.3. MASS PRODUCTION

- Specialized automatic equipment;
- Standardized assembling;

- Flexibility;
- Minimizing variants;
- Simplifying conversion tools;
- Re-using existing tools.

1.2. AUTO DOSING SYSTEM (ADS)

The main role of ADS in producing the alloys is to feed the zirconium sponge and alloying elements to the press to make compacts of different alloys. The raw material which comes in form of lots to the ADS consists of zirconium sponge which contains different compositions of impurities which are indicated on a lot card comes with the lot. By the analysis of the lot card the supervisor decides the type of mix which is to be preparing for the production of different alloys; accordingly the alloying elements are added. The alloying elements are mainly zirconium oxide powder, niobium, tin, nickel, ferrous and chromium. The weight of one compact is generally around 20 kgs. The lot weighs 200 kgs. comes in drums to the ADS.

1.2.1. COMPONENTS OF ADS

The ADS consists of 11 bins for the storage of zirconium sponge and different alloys. The whole system is divided in three zones.

❖ **Zone A**

- The material is fed to the ADS with the help of a skip hoist in which the drum is loaded and there is a motor, which moves in both directions, this helps the skip hoist to lift the drum to the top. One hopper is used to pour the zirconium sponge to the storage bins.
- There are five storage bins B1, B2, B3, B4 and B5.
- Bins B1 to B4 contain zirconium sponge of different compositions according to the impurities present in the lot. The B5 contains zirconium oxide powder (ZrO_2). The capacity of B1-B4 is 500 ltrs and of B5 is 20 ltrs.
- The lids of the bins B1 to B4 are opened and closed with the help of actuators and the lid of the B5 is manually operated.
- The feeding to the bins B1-B4 is done by the hopper through a chute. The chute is rotated by a motor and stops on the corresponding bin.

- There are two weighing bins also, W1 and W2. The capacity of W1 is 30 kgs. with accuracy +/- 30 gms. . The capacity of W2 is 1 kg with accuracy +/- 1 gms..
- The material to these weighing bins is fed by five vibrofeeders F1 to F5. Feeders F1 to F4 feeds W1 and F5 feeds W2. There is one another vibrofeeder FW1 which receives the material from W1.
- Then the material gets transferred from FW1 to a cone blender, which is rotated by a motor to mix the zirconium sponge and zirconium oxide powder. The capacity of cone blender is 40 ltrs. The cone blender has to be purged with Argon gas in order to avoid the fire hazard because zirconium is pyrophoric.

❖ **Zone B**

- This zone consists of two storage bins B6 and B7 both with capacity of 50 ltrs. each. Bin B6 is used for the storage of niobium and B7 is used to store tin pellets.
- There are two vibrofeeder under each bin F6 and F7 respectively; they are used to drop the material in the weighing pan W3.
- There is one weighing pan W3 to weigh the material from the bins B6 and B7.
- The material from this weighing pan is fed to one vibrofeeder FW3.
- There is one more vibrofeeder FC, which receives the material from the cone blender.
- The material from both FC and FW3 is dispensed on one conveyer belt.

❖ **Zone C**

- The number of storage bins are four here, B8 to B11. The storage bin B8 contains zirconium oxide powder and it is of capacity 20 ltrs. The bins B9 to B11 contain iron, nickel and chromium respectively. The capacity of each of the bin is 5 ltrs.
- Each bin is installed with one vibrofeeder under it, which are F8, F9, F10 and F11 respectively.
- There are two weighing pans W4 and W5. W4 weighs the material coming from B8 and W5 weighs the material coming from bins B9-B11. The capacity of W4 is 1 kg with weighing accuracy of +/- 1 gm and the capacity of W5 is 500 gms with accuracy of +/-0.5 gms.

- There are two other vibrofeeders FW4 and FW5, and they receive the material from W4 and W5. Ultimately all this material is fed to the conveyer belt 2.
- This conveyer belt is called telescopic conveyer belt because it can shift itself in two positions with the help of actuators. From this conveyer belt the material is fed to the hydraulic press.

1.2.2. OPERATION OF ADS

As described earlier that the function of ADS is to feed zirconium sponge and alloying elements into the hydraulic press. The zirconium sponge and the alloying elements should be dispensed into the die cavity of the hydraulic press in such a fashion that they should make a sandwich structure either of four layers or three layers that means first layer of zirconium sponge then second alloying elements then third zirconium sponge layer like that till the last layer of zirconium sponge.

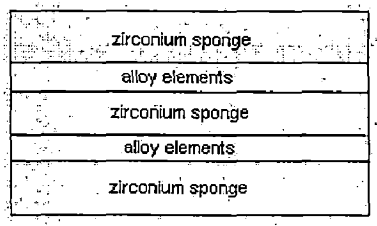


Fig 1.1 Sandwich Structure of Alloy Compact

The sequence of flow of material till die cavity of the hydraulic press is as follows:

- First the material rises up in the skip hoist as the operator presses the load switch.
- From the skip hoist the material is fed to the corresponding bins B1 to B4 according to the commands from the operator.
- With the start command the corresponding vibrofeeder (F1-F4) starts and runs in course speed until the weight in W1 becomes 80% of the set point value, which is decided by the weight of one compact, after that the vibrofeeder starts running in fine mode till the set point reached. Then next vibrofeeder will start if its material is also to be added in the compact same as the first one, similarly others will also function.
- After confirming that the weight in W1 is under tolerance the W1 will get open and pour the zirconium sponge on FW1..

- The filling of B5 is done manually and according to the need (decided by the quantity of the materials shown in the lot card) it is fed to FW1 by weighing it in W2 till the set point reached.
- Before putting the material in the cone blender by FW1 first the swing chute is to be moved up and cone blender lid is to be open and then FW1 will start.
- After pouring all the material in the cone blender the lid is to be closed and rotate for particular number of times and in last the top part of the cone blender will come down and its lid will get open and the material will dispensed into FC.
- Before starting of the FC and conveyer belt 1, the operator must be assured that the ram of the press is up and the conveyer belt two is in required position.
- Then move the conveyer belt 2 to position to dispense the material in die cavity of press and then start it, as soon as conveyer belt 2 starts, start conveyer belt 1.
- At the same time FC also starts but due to required sandwich structure of the compact FC has to run in four/three different installments.
- As the first installment from FC reaches FW1, it will also get start and feed the material which is ready on it in similar fashion of installments on the conveyer belt 1
- The same is from FW4 and FW5, then the whole material is feeds to the die cavity of the hydraulic press and the conveyer belt 2 comes in its earlier position, if the material on conveyer belt 2 more then the required for the compact then belt start moving in reverse direction and the material is disposed to a container kept there, this decision is taken by the operator only.
- After dispensing the material in die cavity the ram of hydraulic press applies high force on the alloys to make a compact.

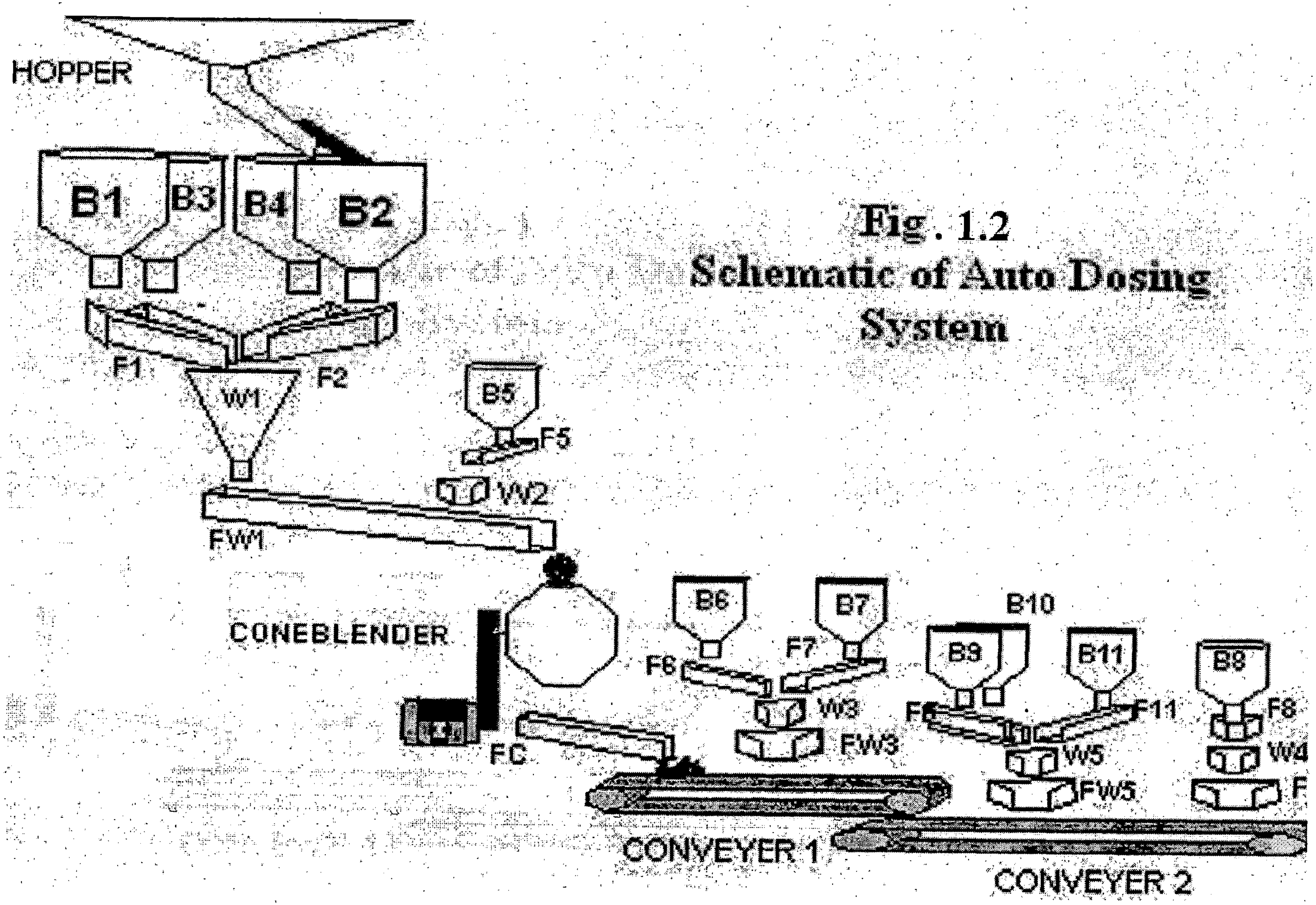


Fig . 1.2
Schematic of Auto Dosing System

1.3. HYDRAULIC PRESS

The 2000 T hydraulic press is the biggest press in NFC. Its main function is to make compacts of different alloys of zirconium. This section describe about the equipments of the press and its operation.

1.3.1. Equipments

The main components of the hydraulic press are:

- Slide: The slide is the main ram, which is used for the pressing operation. The ram applies force on the compact placed in the die.
- Die lift: This consists of a die cavity in which the alloy elements and the zirconium sponge are dispensed. This die moves up and down with the help of cylinders.
- Unloader: This is used to unload the prepared compact from the die cavity. It moves in forward and backward direction with the help of cylinders.
- Pumps: There are three pumps main pump, pilot pump and auxiliary pump. They are used to move the above-mentioned parts of the press.

There are basically three operating modes of the press and a selector switch does switching from one mode to other mode. The three modes are described below:

1.3.2. Auto Mode Operation:

Selector switch is in 'Auto Mode'. Auto cycle command is given to the press through PC then the remaining sequence of operations for the press is same as 'Semi Auto' mode.

1.3.3. Semi Auto:

Selector switch is on Semi Auto function. The basic operations are briefly described here

❖ **Top of the stroke**

Initially slide is at the top of stroke. All solenoids are in de-energized condition. Die lift cylinders in down position. And unloader slide is in retracting position.

❖ **Fast advance:**

Depressing RUN buttons starts the operation and this moves the slide down fast for some time

❖ **Pressing:**

After fast advance the slide starts moving in slow speed till the pressing of the compact is not over. This is done with help of timer.

❖ **Holding:**

After stopping, the slide holds in the die cavity for some time, which is set by a timer. This is done for not allowing the compact to expand which changes the required parameters of the compact.

❖ **Decompression:**

After holding the slide for some time, decompression starts.

❖ **Fast Return:**

After decompression the main operation is to remove the compact from the die, for this the slide moves up again with fast speed and then the die lift moves upward. Then the unloader moves forward to get the prepared compact from the die. As the unloader comes below the die lift the slide again moves down and removes the compact from die and shifts it to the unloader. Then the unloader retracts and drags the compact out and dispense in the container.

1.3.4. Inch function

Selector switch is in inch mode. In this mode the operations are carried in discrete fashion by moving the parts inch wise with the help of buttons. The main operations are follows:

❖ **Inch down:**

Depressing inch down drives the slide to move down in pressing speed till it reaches the die cavity or inch down button is released.

❖ **Inch up:**

Depressing inch up button drives slide to move up till the inch up button is released or interlock is not satisfied.

After this operation of the die lift cylinder started by first pressing the die lift cylinder inch up button, to move the die lift up, then unloader slide inch forward is pressed to move the unloader inside. Then the slide comes down by pressing the inch down for the slide this removes the compact from the die. Then the unloader slide inch retract is pushed to retract the slide. Again the die lift has to bring down by pressing the inch down button for die lift.

SCHEMATIC OF THE 2000 T HYDRAULIC PRESS

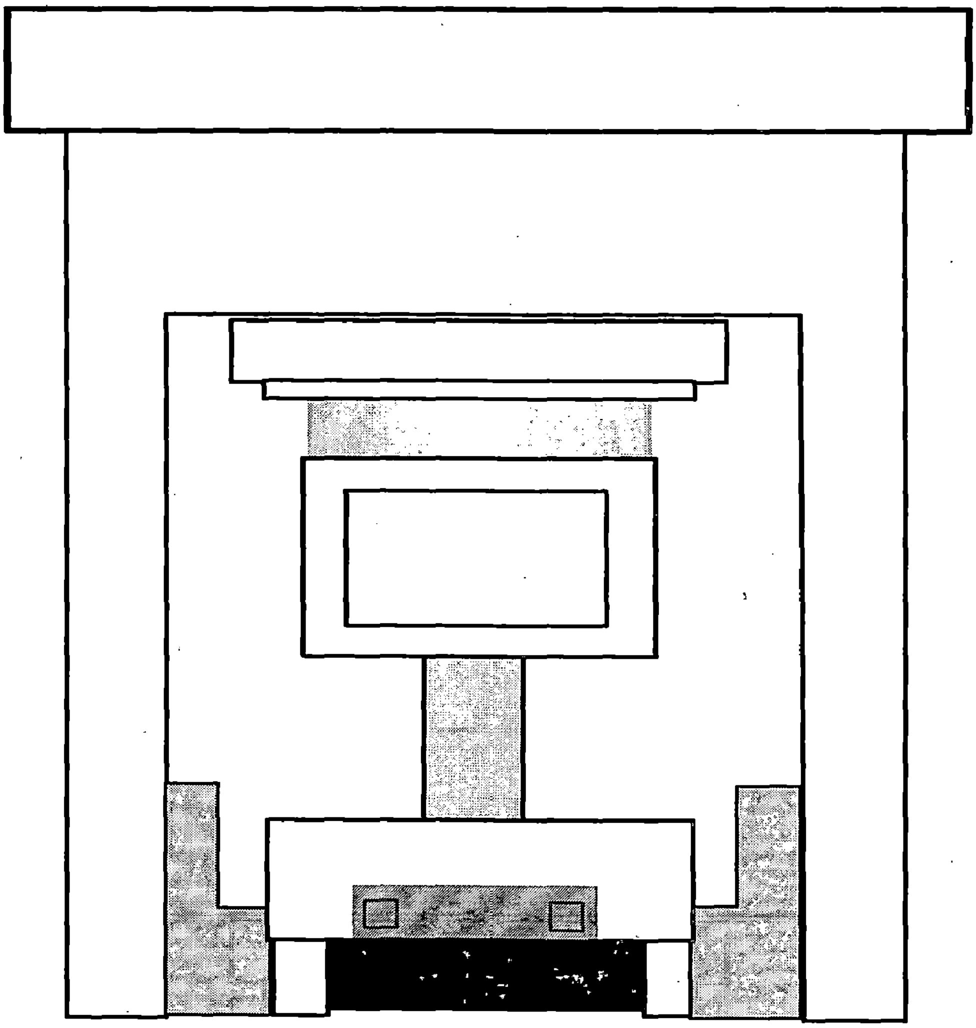


Fig 1.3. Schematic of Hydraulic Press

1.4. ORGANISATION OF THESIS

The whole thesis of dissertation is distributed in four chapters.

Chapter 1: Introduction: this chapter covers the introduction of Melt Shop of NFC, Hyderabad, basic points about general Auto Dosing System, description of ADS of Melt Shop, description of Hydraulic Press operations.

Chapter 2: Automation of the System: this chapter describes the components required for the automation of the Dosing System like sensors, PLC, PC.

Chapter 3: Logic Analysis: This chapter describes the logic developed for the operation of ADS.

Chapter 4: Human Machine Interface: this section describes the features of general HMI and the CIMPLICITY. It also describes the function of each and every screen developed for this dissertation.

As the name of the system describes Automatic Dosing System means it utilizes the automation techniques for its sequential operations. The main parts of the automation are the sensors, actuators, PLC and the PC. This chapter describes about the sensors and used in the system and basics of PLC.

2.1. SENSORS AND TRANSDUCERS

A sensor is a device to detect changes in the environment such as energy, heat, light, magnet, supersonic, etc. and converts them to electric signals. Some simple sensors can distinguish between only two different states of the measured variable. Such sensors are called switches. Other sensors, called transducers, provide output signals (usually electrical) that vary in strength with the condition being sensed. Figure 2.1 shows the difference in outputs of a switch and a transducer to the same sensed condition.

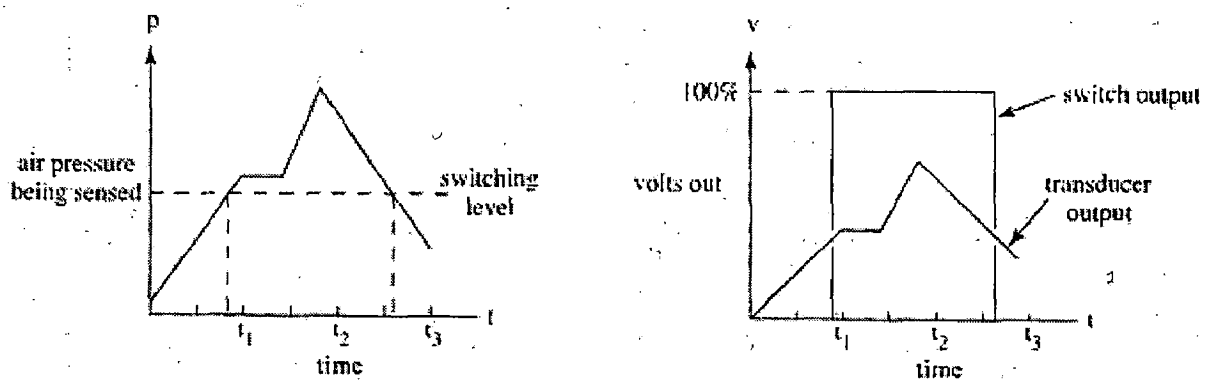


Fig. 2.1. Switch output versus transducer output (switch without hysteresis)

2.1.1. Switches

The most commonly used sensor in industry is still the simple, inexpensive **limit switch,** shown in Figure 2.2. These switches are intended to be used as presence sensors. When an object pushes against them, lever action forces internal connections to be changed. Most switches can be wired as either **normally open** (NO) or **normally closed** (NC). If a force is required to hold them at the other state, then they are **momentary contact** switches. Switches that hold their most recent state after the force is removed are called **detent** switches.

Most switches are **single throw** (ST) switches, with only two positions. Switches that have a center position, but can be forced in either direction, to either of two sets of contacts, are called **double throw (DT).** Most double throw switches do not close any circuit when in the center (normal) position, so the letters "co," for center off, may appear on the spec sheet. Switches that change more than one set of contacts ("poles") with a single "throw" are also available. These switches are called **double pole (DP), triple pole (TP),** etc., instead of the more common **single pole** (SP). In switches designed for high current applications; the contacts are made crude but robust, so that arcing does not destroy them. For small current applications, typical in computer controlled applications, it is advisable to use sealed switches with plated contacts to prevent even a slight corrosion layer or oil film that may radically affect current flow. Small limit switches are often called **microswitches.**

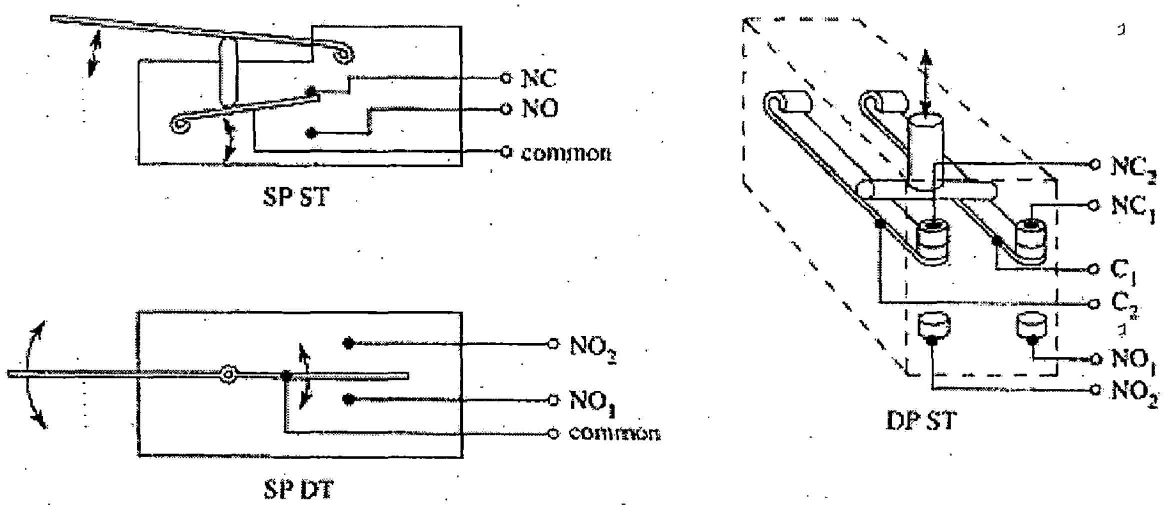


Fig.2.2. Limit Switches.

2.1.2. Non-Contact Presence Sensors (Proximity Sensors)

The limit switches discussed in the previous section are "contact" presence sensors, in that they have to be touched by an object for that object's presence to be sensed. Contact sensors are often avoided in automated systems because wherever parts touch there are wear and a potential for eventual failure of the sensor. Automated systems are increasingly being designed with non-contact sensors. The three most common types of non-contact sensors in use today are the **inductive proximity** sensor, the **capacitive proximity** sensor, and the **optical proximity** sensor. All of these sensors are actually transducers, but they include control circuitry that allows them to be used as switches. The circuitry changes an internal switch when the transducer output reaches a certain value

❖ **Inductive proximity sensors**

The **inductive proximity sensor** is the most widely used non-contact sensor due to its small size, robustness, and low cost. This type of sensor can detect only the presence of electrically conductive materials. Figure 2.3 demonstrates its operating principle.

The supply DC is used to generate AC in an internal coil, which in turn causes an alternating magnetic field. If no conductive materials are near the face of the sensor, the only impedance to the internal AC is due to the inductance of the coil. If, however, a conductive material enters the changing magnetic field, eddy currents are generated in that conductive material, and there is a resultant increase in the impedance to the AC in the proximity sensor. A current sensor, also built into the proximity sensor, detects when there is a drop in the internal AC current due to increased impedance. The current sensor controls a switch providing the output.

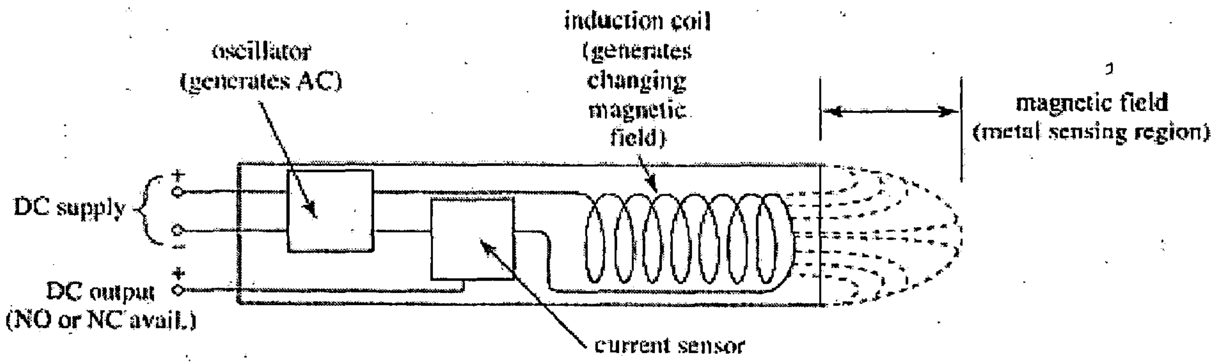


Fig 2.3. Inductive Proximity Sensors.

❖ **Capacitive proximity sensors**

Capacitive proximity sensors sense "target" objects due to the target's ability to be electrically charged. Since even non-conductors can hold charges, this means that just about any object can be detected with this type of sensor. Figure 2.4 demonstrates the principle of capacitive proximity sensing.

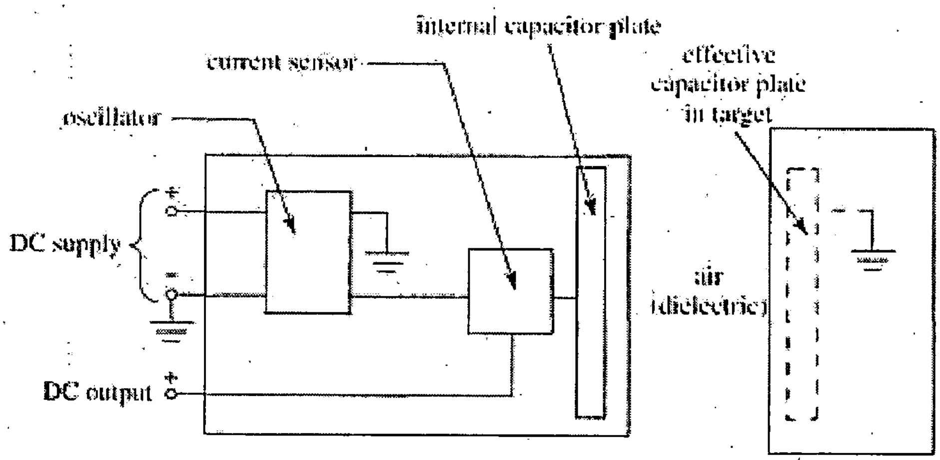


Fig 2.4 Capacitive Proximity Sensors.

Inside the sensor is a circuit that uses the supplied DC power to generate AC, to measure the current in the internal AC circuit, and to switch the output circuit when the amount of AC current changes. Unlike the inductive sensor, however, the AC does not drive a coil, but instead tries to charge a capacitor. Remember that capacitors can hold a charge because, when one plate is charged positively, negative charges are attracted into the other plate, thus allowing even more positive charges to be introduced into the first plate. Unless both plates are present and close to each other, it is very difficult to cause either plate to take on very much charge. Only one of the required two capacitor plates is actually built into the capacitive sensor. The AC can move current into and out of this plate only if there is another plate nearby that can hold the opposite charge. The target being sensed acts as the other plate. If this object is near enough to the face of the capacitive sensor to be affected by the charge in the sensor's internal capacitor plate, it will respond by becoming oppositely charged near the sensor, and the sensor will then be able to move significant current into and out of its internal plate.

❖ **Optical proximity sensors**

Optical proximity sensors generally cost more than inductive proximity sensors, and about the same as capacitive sensors. They are widely used in automated systems because they have been available longer and because some can fit into small locations. These sensors are more commonly known as **light beam sensors** of the **thru-beam** type or of the **retro reflective** type. Both sensor types are shown in Figure 2.5.

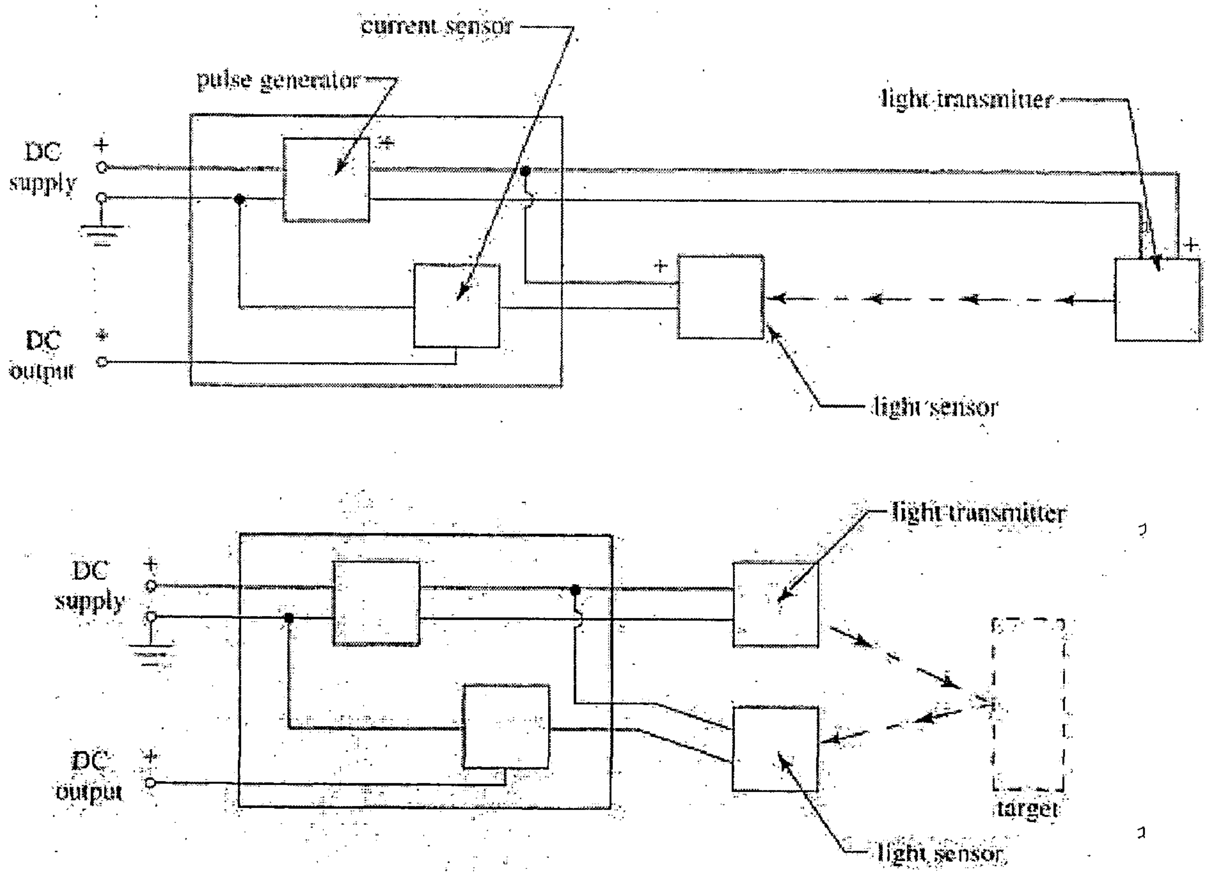


Fig. 2.5 Optical Proximity Sensors.

The **light source** is supplied because it is usually critical that the light be "tailored" for the light sensor system. The light source generates light of a frequency that the light sensor is best able to detect, and that is not likely to be generated by other nearby sources. **Infra-red light** is used in most optical sensors. To make the light sensing system more foolproof, most optical proximity sensor light sources **pulse** the infra-red light on and off at a fixed frequency. The light sensor circuit is designed so that light that is not pulsing at this frequency is rejected.

The **light sensor** in the optical proximity sensor is typically a semiconductor device such as a photodiode, which generates a small current when light energy strikes it, or more commonly a phototransistor or a photo darlington that allows current to flow if light strikes it. Early light sensors used photoconductive materials that became better conductors, and thus allowed current to pass, when light energy struck them.

2.1.3. Load Cell

A load cell is classified as a force transducer. This device converts force or weight into an electrical signal. The strain gauge is the heart of a load cell. A strain gage is a device that changes resistance when it is stressed. The gages are developed from an ultra-thin heat-treated metallic foil and are chemically bonded to a thin dielectric layer. "Gauge patches" are then mounted to the strain element with specially formulated adhesives. The precise positioning of the gauge, the mounting procedure, and the materials used all have a measurable effect on overall performance of the load cell. Each gauge patch consists of one or more fine wires cemented to the surface of a beam, ring, or column (the strain element) within a load cell. As the surface to which the gauge is attached becomes strained, the wires stretch or compress changing their resistance proportional to the applied load. One or more strain gauges are used in the making of a load cell. Multiple strain gauges are connected to create the four legs of a Wheatstone-bridge configuration. When an input voltage is applied to the bridge, the output becomes a voltage proportional to the force on the cell. This output can be amplified and processed by conventional electrical instrumentation.

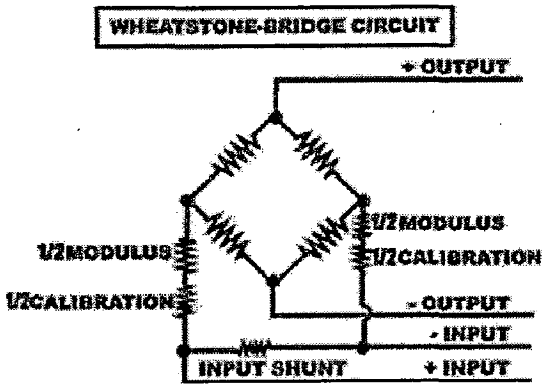


Fig 2.6 Wheatstone Bridge

❖ **Cantilever Load Cells**

Shear strain beam for use in all process weighing applications and also engineering force in compression or tension. These load cells are ideally suited to process weighing applications which have harsh environmental requirements. The design configuration allows them to be used for installations for tank, hopper, weigh platforms or weigh bridges.

Ranges: 0.5, 1, 2, 4, 8, 12 and 16 tonne.

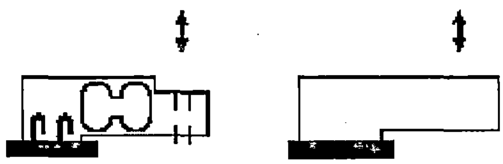


Fig 2.7 Cantilever Load Cell

2.2. ACTUATORS

2.2.1. Pneumatic Cylinders

Compressed air is a form of energy. In order to put it to work, you need to turn the energy into something like motion. This is frequently done with a pneumatic cylinder. A pneumatic cylinder simply converts air pressure into linear motion. A "double-acting" cylinder has two ports for compressed air.

A "double-acting" cylinder has two ports for compressed air.

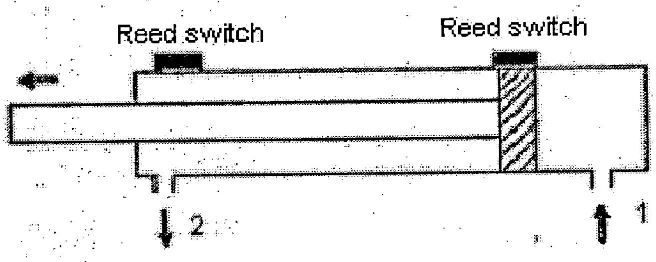


Fig 2.8 Double Acting Cylinder

There are two ports in the cylinder and when the air enters from port 1 the piston moves in forward direction and when the air enters from port 2 the piston moves in backward direction. The rod of the piston is connected to the part of machine which has to be moved. In ADS the lids of most of the bins are operated through these Double Acting Cylinders.

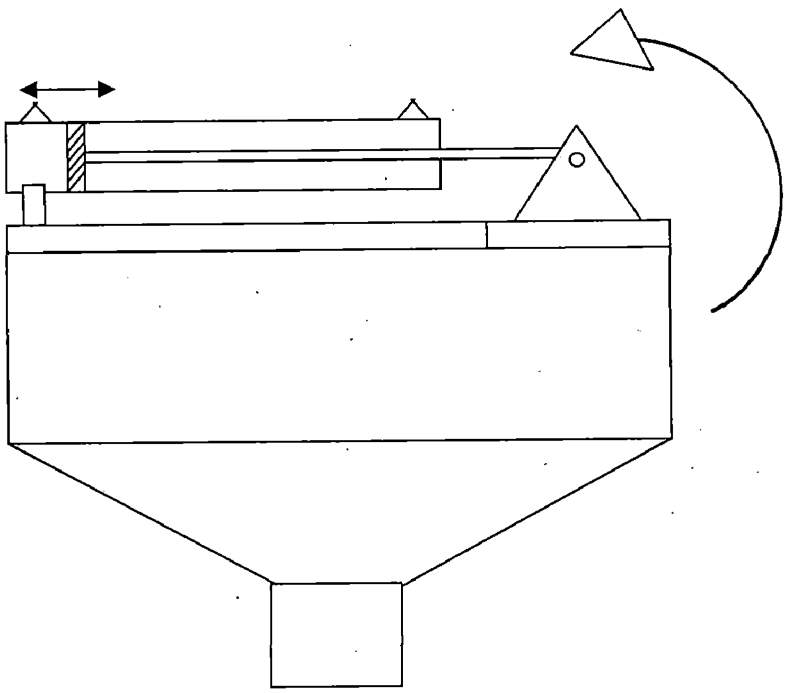


Fig 2.9 Double Acting Cylinder in Storage Bin lid

2.3. PROGRAMMABLE LOGIC CONTROLLERS (PLC):

The basic function of a programmable controller is to provide output commands to a machine or process that are based on some combination of input conditions received from the machine or process or other related conditions. The internal wiring of a programmable controller is fixed and the logic function which it must perform in a given application are programmed into its memory and hence the name "PROGRAMMABLE CONTROLLER". A processor with built in routine SCANS the incoming signals and in accordance with the programs stored in the memory, initiates corresponding output signals. The new PLC that is planned to be installed for this system is the latest Siemens make SIMATIC S7-300. The software used for the same is **STEP-7.**

Definition : As per NEMA Standards a programmable controller is defined as a "DIGITALLY OPERATING ELECTRONIC APPARATUS" which uses a Programmable memory for the storage of instructions for specific functions such as logic sequencing, timing, counting, and arithmetic control through digital or analog input/output modules, various types of machines or processes. A digital computer, which is used to perform the function of a programmable controller, is considered to be within this scope.

2.3.1. Constituents of PLC

The PLC is basically a programmable interface between the field input elements like limit switches, sensors, transducers, push buttons etc. and the final control elements like actuators, solenoids valves, drives, LEDs etc.

- Central Processing Unit (CPU)
- Input Module.
- Output Module.
- Bus System.
- Power Supply.

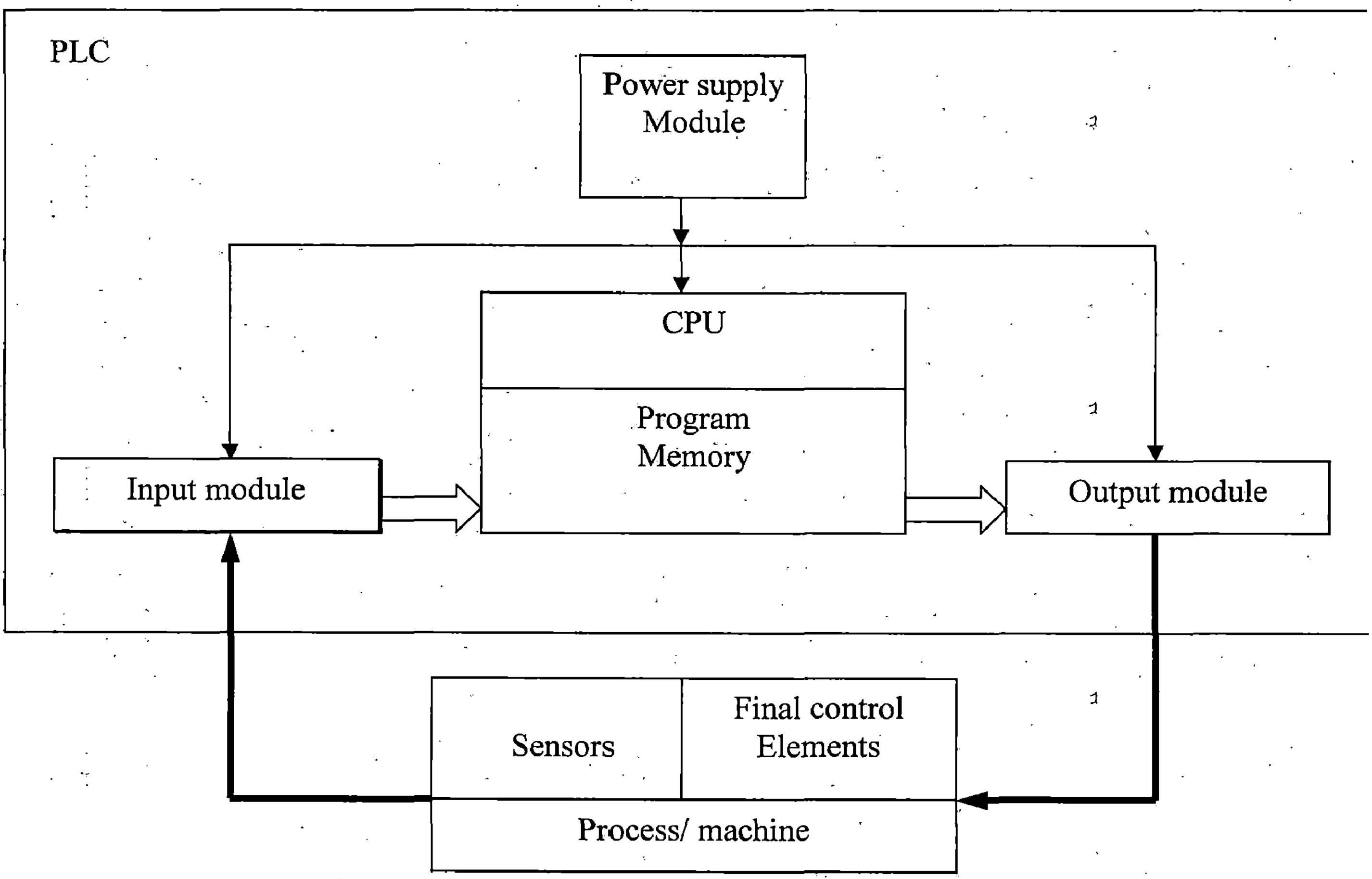


Fig 2.10 Functional Block Diagram of PLC

❖ **Input Module:**

- It converts the field signals into a standard control signal for processing by PLC. The standard control input delivered by the input module could be 5V or 9V whereas the field signal received by it could be say 24V DC or 230V AC.
- Multiplexing of the inputs, thereby helping in serial communication.
- It can be analog or digital depending upon the type of the input.
- Typical analog current input modules are 4 to +/- 20 mA, 0 to +/-20mA and analog voltage input module are 0 to +/- 50mV, 0 to +/- 500mV & 0 to +/- 10V.
- Typical digital input modules are 24V dc, 120V AC and 230V AC.

❖ **Central Processing Unit:**

The CPU consists of the following:

- Arithmetic logic unit (ALU)
- Program memory.
- Process image memory (i.e. internal memory of the CPU)
- Internal timers and counters.

❖ **Output Module:**

- The output module converts the output signal delivered by CPU into the appropriate voltage level suitable for the output field device.
- The voltage level provided by the CPU could be 5V of 9V, but the output module converts this voltage to say, 24V dc, 120V AC or 230V AC.

❖ **Power Supply:**

The power supply module generates the voltages required by the electronic modules of the PLC from mains supply. Typically 1 phase, 230V AC supply is converted into 24V DC for the power supply module. It should be noted that CPU needs 24V DC input and other voltages required by the PLC hardware such as 5V DC etc. is generated by the CPU.

❖ **Additional Modules:**

In addition to the above listed modules the PLC may use other modules like

- Interface module.
- Communication processor module.
- Position control module.
- High speed module.

2.3.2. WORKING OF PLC:

PLC carries out its operation in three steps:

❖ **Bringing Input Status Signals To The Internal Memory Of CPU:**

- At the beginning of each cycle the CPU brings in all the field input signals from input module and stores them into its internal memory as **process input image** of input signal. This internal memory of CPU is called as **PII.**

- The programmable controller operates cyclically meaning when complete program has been scanned; it starts again at the beginning of the program.

❖ **Processing Of Signals Using Program & Updating PiQ:**

- Once the field status is brought into the internal memory of the CPU i.e. in **PII,** the execution of the user program, statement-by-statement begins. Based on the user program the CPU performs logical and arithmetic operations on the data from **PII.**
- It also processes timers and counters as well as flag states based on the instructions.
- The results of the user program scan i.e. decisions are then stored in the internal memory of CPU. This memory is called **process image output** or **PiQ.**

❖ **Sending Process Image Output To Output Module:**

At the end of the program run i.e. at the end of scan cycle, the CPU transfers the signal states in the process image output to the output module and further to field controls.

2.3.3. FACTS ABOUT PLC PROGRAMMING:

- The programming language used in programming of SIEMENS make PLC is called “STEP-5” for SIMATIC S5 family PLC or STEP-7 for SIMATIC S7 family of PLCs.
- With STEP-7 / STEP-5 language the user can communicate with SIEMENS make PLC, respectively SIMATIC S5 and SIMATIC S7-300 / 400.
- The programming of the PLC can be done on the general purpose PC by loading it with STEP-5 or STEP 7 software and then the program can be loaded using an ADAPTOR. An adaptor is a serial communication provided from the PC to CPU of PLC.
- The programming can be done off-line and on-line. Off-line programming means writing the programming instructions in the PC and not in the User Memory.

- On line programming means the programming unit is directly connected to the programming port of the CPU and then the instructions are directly written in the user memory of the CPU.

2.3.4. FORMS OF PROGRAMMING LANGUAGES:

One of the important features of STEP-7 / STEP-5 programming language is its tremendous flexibility. We can write program in any one of the following forms:

❖ **Statement List:**

This method of programming uses mnemonic abbreviations in programming. **The statement** consists of:

- An **operation**, which specifies what, is to be done. **A** indicates AND operation to be done, **O** indicates OR operation to be done etc.
- An **operand**, which specifies where the operation is to be done. It consists of **operand identifier & parameter.** For instance I 2.3 conveys that the operation is to be done on the signal at input (indicated by I) with address 2.3

The complete statement in this case is:

A I 2.3

❖ **Control System Flowchart (CSF) / Functional Block Diagram (FBD):**

The control System Flow Chart method (CSF) / Function Block Diagram (FBD) uses graphical symbols to formulate the control task. e.g.

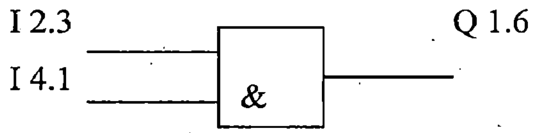


Fig 2.11 Graphic Symbol of AND Logic

This method is preferred by those who are more familiar with logic symbols / logical machine and process sequence.

❖ **Ladder Diagram (LAD):**

The ladder diagram uses relay logic symbols to formulate the control task. This arrangement gives the LAD method the appearance of the schematic circuit diagram of a hard-wired control.

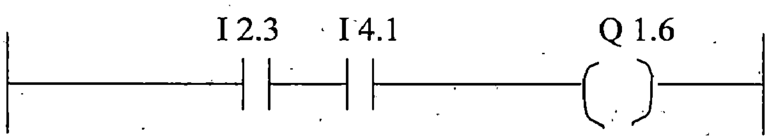


Fig 2.12 Ladder Diagram of AND Logic

2.4. COMMUNICATION BETWEEN PC AND PLC

Different types of connections do communication between PC and PLC. Serial linkages are far more common between computers and PLCs because very high speed communication is not essential for proper performance. A serial link transfers the data as a string of pulses. Additional bits are required for synchronization and error detection. Typical transmission speeds are from 1200 bits per second to 19,200 bits per second.

2.4.1. SERIAL LINKS

A primary consideration in the industries is that the data transmission is cheap and reliable. For this reason the standard topology at the field level is the serial bus on which data are sent sequentially. Some of the interface standards for data transmission, which are frequently used at the field level, are RS-232C, RS-422, RS-485, and current loop. The data transmission between the PLC used with the auto dosing system is done by both RS-232C and RS-485.

RS-232 stands for Recommended Standard number 232 and C is the latest revision of the standard. The serial ports on most computers use a subset of the RS-232C standard. The full RS-232C standard specifies a 25-pin "D" connector of which 22 pins are used. Most of these pins are not needed for normal PC communications, and indeed, most new PCs are equipped with male D type connectors having only 9 pins.

RS-485 is a standard for multipoint communication. It supports several types of connectors including DB-9 and DB-37. RS-485 which specifies bi-directional, half duplex data transmission is the only Electronic Industry Association (EIA) standard that allows multiple receivers and drivers in bus configurations. The table on the next page compares the specifications of RS-232 and RS-485.

Specifications	RS232	RS485
Mode of Operation	Single-Ended	Differential
Allowed no. of Tx and Rx	1 Tx, 1 Rx	32 Tx, 32 Rx
Maximum cable length	50 feet	4000 feet
Maximum data rate	20 kbps	100 kbps/10 mbps
Minimum driver output range	+/- 5 V to +/- 15 V	+/- 1.5 V
Maximum driver output range	+/- 25 V	+/- 6 V
Tx load impedance (Ohms)	3k to 7k	54
Rx input sensitivity	+/- 3V	+/- 200 mV
Rx input voltage range	+/- 15 V	-7 V to +12 V
Maximum Rx input resistance(Ohms)	3k to 7k	>=12k

Table 2.1 Features of RS232 and RS485

2.4.2. COMMUNICATION PROTOCOL

The major limitation of serial data communication is that the information transmitted has no specific meaning. Unlike in parallel wiring scheme, there is no physical attribute to tie the information to a particular meaning. A protocol must be agreed by both the parties (PC and PLC) defining the meaning of information transmitted across the serial links. Usually a message is prefaced with identifiers specifying the block of data to follow, and then the actual data.

There are different types of communication protocols supported by different PLCs. They are as follows:

❖ **Modbus Protocol**

The common language used by all Modicon controllers is the Modbus protocol. This protocol defines a message structure that controllers will recognize and use, regardless of the type of networks over which they communicate. It describes the process a controller uses to request access to another device, how it will respond to requests from the other devices, and how errors will be detected and reported. It establishes a common format for the layout and contents of message fields. During communications on a Modbus network, the protocol determines how each controller will know its device address, recognize a message addressed to it, determine the kind of action to be taken, and extract any data or other information contained in the message. If a reply is required, the controller will construct the reply message and send it using Modbus protocol.

❖ **Transactions on Modbus Networks**

Standard Modbus ports on Modicon controllers uses an RS–232C compatible serial interface that defines connector pin outs, cabling, signal levels, transmission baud rates, and parity checking. Controllers can be networked directly or via modems. Controllers communicate using a master–slave technique, in which only one device (the master) can initiate transactions (called 'queries'). The other devices (the slaves) respond by supplying the requested data to the master, or by taking the action requested in the query. Typical master devices include host processors and programming panels. Typical slaves include programmable controllers. The master can address individual slaves, or can initiate a broadcast message to all slaves. Slaves return a message (called a 'response') to queries that are addressed to them individually. Responses are not returned to broadcast queries from the master. The Modbus protocol establishes the format for the master's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error–checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error–checking field. If an error occurred in receipt of the message, or if the slave is unable to perform the requested action, the slave will construct an error message and send it as its response.

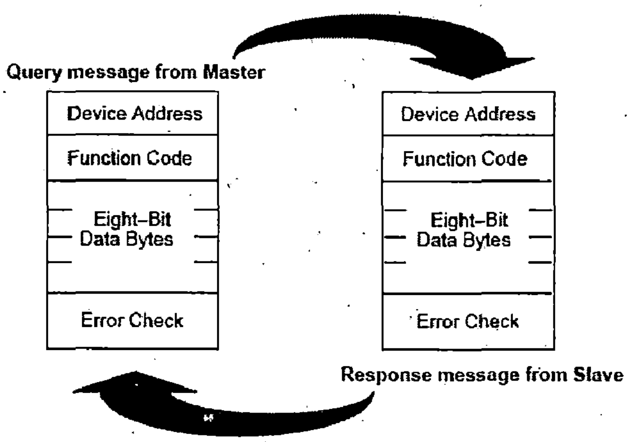


Fig 2.13 Query Response Cycle

❖ The Two Serial Transmission Modes

Controllers can be setup to communicate on standard Modbus networks using either of two transmission modes: **ASCII** or **RTU**. Users select the desired mode, along with the serial port communication parameters (baud rate, parity mode, etc), during configuration of each controller. The mode and serial parameters must be the same for all devices on a Modbus network.

- **ASCII Mode**

When controllers are setup to communicate on a Modbus network using ASCII (American Standard Code for Information Interchange) mode, each 8–bit byte in a message is sent as two ASCII characters. The main advantage of this mode is that it allows time intervals of up to one second to occur between characters without causing an error. The format for each byte in ASCII mode is:

Coding System:	Hexadecimal, ASCII characters 0–9, A–F One hexadecimal character contained in each ASCII character of the message
Bits per Byte:	1 start bit 7 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field:	Longitudinal Redundancy Check (LRC)

In ASCII mode, messages start with a 'colon' (:) character (ASCII 3A hex), and end with a 'carriage return – line feed' (CRLF) pair (ASCII 0D and 0A hex). The allowable characters transmitted for all other fields are hexadecimal 0–9, A–F. Networked devices monitor the network bus continuously for the 'colon' character. When one is received, each device decodes the next field (the address field) to find out if it is the addressed device. Intervals of up to one second can elapse between characters within the message. If a greater interval occurs, the receiving device assumes an error has occurred. A typical message frame is shown below.

Start	Address	Function	Data	LRC check	End
1 CHAR	2 CHAR	2 CHAR	N CHAR	2 CHAR	2 CHAR CRLF

Table 2.2 Data Frame in ASCII Mode

- **RTU Mode**

When controllers are setup to communicate on a Modbus network using RTU (Remote Terminal Unit) mode, each 8–bit byte in a message contains two 4–bit hexadecimal characters. The main advantage of this mode is that its greater character density allows better data throughput than ASCII for the same baud rate. Each message must be transmitted in a continuous stream. The format for each byte in RTU mode is:

Coding System: 8–bit binary, hexadecimal 0–9, A–F
Two hexadecimal characters contained in each
8–bit field of the message

Bits per Byte: 1 start bit
8 data bits, least significant bit sent first
1 bit for even/odd parity; no bit for no parity
1 stop bit if parity is used; 2 bits if no parity

Error Check Field: Cyclical Redundancy Check (CRC)

Start	Address	Function	Data	CRC check	End
T1-T2-T3-T4	8 BITS	8 BITS	N*8 BITS	16 BITS	T1-T2-T3-T4

Table 2.3 Data Frame in RTU Mode

❖ CRC Checking

In RTU mode, messages include an error–checking field that is based on a Cyclical Redundancy Check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message.

The CRC field is two bytes, containing a 16–bit binary value. The CRC value is calculated by the transmitting device, which appends the CRC to the message. The receiving device recalculates a CRC during receipt of the message, and compares the calculated value to the actual value it received in the CRC field. If the two values are not equal, results an error.

The CRC is started by first preloading a 16–bit register to all 1's. Then a process begins of applying successive 8–bit bytes of the message to the current contents of the register. Only the eight bits of data in each character are used for generating the CRC. Start and stop bits, and the parity bit, do not apply to the CRC.

During generation of the CRC, each 8–bit character is exclusive ORed with the register contents. Then the result is shifted in the direction of the least significant bit (LSB), with a zero filled into the most significant bit (MSB) position. The LSB is extracted and examined. If the LSB was a 1, the register is then exclusive ORed with a preset, fixed value. If the LSB was a 0, no exclusive OR takes place. This process is repeated until eight shifts have been performed. After the last (eighth) shift, the next 8–bit byte is exclusive ORed with the register's current value, and the process repeats for eight more shifts as described above. The final contents of the register, after all the bytes of the message have been applied, is the CRC value. When the CRC is appended to the message, the low-order byte is appended first, followed by the high-order byte.

This chapter shows the logic analysis part of the system in textual form. The logic analysis is the logic of interlocks to operate the actuators. The dots bullets shows the AND operation between the interlocks.

Textual description of interlocks

By load command the motor of the skip hoist starts lifting the drum to dispense the material into the storage bins through a hopper and the moving chute. Before loading there are lots of interlocks or conditions to check like whether the lid of the respective bin is open or closed and chute is ON that bin. So we start with the opening of the lid of the bin.

3.1. Interlocks to dispense the lot in the bins.

- ❖ Open the lid of the bin
  - Required bin is selected.
  - Bin is not full.
  - The lid of the bin is closed.
  - Chute position is not above the required bin to be fill.
- ❖ If the chute above the required bin it needs to be displaced
  - Chute is above the bin.
  - Lid of the bin is closed.
  - Required bin is selected.
- ❖ Chute moves until it comes back above the opened bin.
  - Chute is not above the bin.
  - Lid is open.
  - Required bin is selected.
- ❖ Chute stays above the bin until a set time and move again to close the bin.
  - Chute is not above the bin.
  - Bin is open.
- ❖ Upward motion of the skip hoist.

  Skip hoist upward movement is allowed Only if:
  - Hopper is open

- The motor is not overload.
- Chute is ON the required bin.
- Lid of the bin is open.
- Upper limit switch closed (normally closed).
- Feedback from the downward motion.

❖ Downward motion

- Lower limit switch is closed (NC).
- Feedback from the upward motion.

For making the required number of compacts from a lot a counter has been set to repeat the operations until the required number of compacts has been made. Let say n number of compacts are required and initially the counter C1 is 0 and increment till n.

For C1 = 0 to n

{

3.2. Interlocks for the movement of the vibrofeeders.

❖ To stop the course speed of the vibrofeeder below the required bin.

- W1 is closed.
- Required bin is selected.
- Weight in W1 is above the 80% of the set point.
- Feedback from the fine speed.
- C1 is not equal to n.

❖ To stop the fine movement of the vibrofeeder.

- W1 is closed.
- Required bin is selected.
- Weight in W1 is above the set point value.
- The weight is between the tolerance value.
- Feedback from the course speed.

3.3. Interlocks to open W1

- Weight of the material from each feeder is under tolerance.

Increment the counter by 1 by opening of W1.

3.4. Interlocks for dispensing the material in the cone blender.

- ❖ The swing chute is up.
  - Cone blender is ON top.
  - Cone blender is close.
- ❖ Open the cone blender
  - Cone blender is ON top.
  - Swing chute is up.
  - Cone blender is not open.
- ❖ Motion of the vibrofeeder FW1.
  - Cone blender is ON top.
  - Swing chute is down.
  - Cone blender is open.
- ❖ Motion of vibrofeeder F5.
  - B5 is not empty
  - W2 is horizontal.
  - B5 is selected.
  - The weight in W2 is below set point.
  - The weight is not under tolerance.
- ❖ Tilting of the W2.
  - Select B5.
  - Weight in W2 equal set point.
  - FW1 is ON.

3.5. Interlocks for the dispensing the material from cone blender to vibrofeeder FC

- ❖ Swing chute up.
  - After feeding the whole material from FW1 to cone blender by a timer T6.
- ❖ Cone blender close.
  - Swing chute up.
  - After time lag from T6.

- Purge Argon Gas in cone blender.
    - Cone blender in to position.
    - Cone blender is closed.
- Rotate cone blender to mix zirconium sponge and oxide powder.
    - Swing chute up.
    - Cone blender close.
    - Counter C1 after three and half rotation and cone blender is in down position.
- Open cone blender.
    - Cone blender down.
    - Three and half rotations of the cone blender.
- Close the cone blender to rotate it back to top position.
    - After a time lag given by timer T8 taken to dispense the mixer ON the FC.
- Close W1.

3.6. Interlocks for dispensing the material from W3 to FW3.

- Motion of F6.
    - B6 is selected.
    - W3 horizontal.
    - Weight in W3 is below the set point value.
    - F7 is stopped.
    - B6 is not empty.
    - Weight is not in tolerance.
- Motion of F7.
    - B7 is selected.
    - W3 horizontal.
    - Weight in W3 is below set point value.
    - F6 is stopped.
    - B7 is not empty.

- Tilt W3.
  - After stopping of both of the feeders F6 and F7.

3.7. Interlocks for dispensing the alloy elements from W4 to FW4.

- Motion of F8.
  - B8 is selected.
  - W4 horizontal.
  - Weight in W4 is below the set point value.
  - B8 is not empty.
  - Weight is not under tolerance range.
- Tilt W4.
  - After stopping of the feeder F8.
  - Tilt again to horizontal after a fix time by a timer.

3.8. Interlocks for dispensing material from W5 to FW5.

- Motion of F9.
  - B9 is selected.
  - W5 horizontal.
  - Weight in W5 is below the set point value.
  - F10 and F11 are stopped.
  - B9 is not empty.
  - Weight is not under tolerance range tolerance.
- Motion of F10.
  - B10 is selected.
  - W5 horizontal.
  - Weight in W5 is below the set point value.
  - F9 and F11 are stopped.
  - B10 is not empty.
  - Weight is not under tolerance range.
- Motion of F11.
  - B11 is selected.

- W5 horizontal.
- Weight in W5 is below the set point value.
- F9 and F10 are stopped.
- B6 is not empty.
- Weight is not under tolerance range.

❖ Tilt W5.

- After stopping of all three of the feeders F9, F10 and F11.
- Tilt again to horizontal after a fix time by a timer.

3.9. Interlocks for dispensing the material from conveyer belt 2 to the die cavity of the hydraulic press.

❖ Move the conveyer belt 2 to position (2) close to die cavity.

- Ram up signal from press.
- Conveyer belt 1 off.

❖ Motion of conveyer belt 2

- Conveyer belt in position (2).

Either

- Cone blender open.
- Cone blender down.

Or

- Conveyer belt 2 ON.

❖ Motion of conveyer belt 1

- Conveyer belt 2 is ON.

The vibrofeeders FC, FW3, FW4, and FW5 dispense the total material on the conveyer belts in installments to accomplish the sandwich pattern of the compact in the die. So a counter has been applied according to the number of the layers (2 layer sandwiching or 3 layer sandwiching). Let say I is counter and 3 layer structure is required then

For I = 0 to 3

{

❖ Movement of FC.

- Conveyer belt 1 is in motion.

- Conveyer belt 2 is in motion.
- Timer T17 is ON.
- I is not equal to 3.

❖ Movement of FW3.

- Conveyer belt 1 is in motion.
- Conveyer belt 2 is in motion.
- Timer T22 is ON.
- I is not equal to 3.

❖ Movement of FW4.

- Conveyer belt 1 is in motion.
- Conveyer belt 2 is in motion.
- Timer T25 is ON.
- I is not equal to 3.

❖ Movement of FW5.

- Conveyer belt 1 is in motion.
- Conveyer belt 2 is in motion.
- Timer T17 is ON.
- I is not equal to 3.

Increment the counter.

}

Reset the counter by

- Cone blender down.
- Cone blender open.

❖ Stop the conveyer belt 2.

- I is equal to 3.
- FC, FW3, FW4, and FW5 are stopped.

❖ Stop the conveyer belt 1.

- Conveyer belt 2.
- FC, FW3, FW4, and FW5 are stopped.
- I is equal to 3.

} **"END OF THE COUNTER C1"**

The HMI is where people and technology meet. The HMI is a combination of people and equipment interacting to produce a desired result from given input. The majority of industrial control system are needed sophisticated HMI.

One of the key reasons to integrate PLCs and computers is to is to obtain superior man machine interface. PLCs generally do not have an embedded HMI. The PLC system has processing capability and excellent I/O system for digital information. The HMI has a graphic display system in the form of an operator station. To take the advantage of this it is necessary to have the PLC and PC shared information. The PLC must provide the status of controlled devices to the pc, and the pc must provide the control signals, which will start and stop a particular motor or group of motors, or open and close valves. Integration can inform the operator when a requested action is inhibited and can advise the operator what is preventing the action from occurring. The computers have CRT based interfaces; some are text based and use cryptic (to the uninitiated) series of commands or instructions. By having a simple function key or touch screen button as a means for starting a computer program for advanced control operators can use a familiar and well understood interface.

4.1 SUPERVISORY CONTROL

While PLCs have superior sequencing capabilities, computers are better suited for advanced control. Because supervisory control is related to product changes,. process optimization, or other "less than real time" functions general-purpose computer will usually suffice.

4.2. GENERIC FEATURES OF HMI [6]

1. CRT based operator consoles and keyboards, which are used by the plant operators and engineers to monitor and control the process.
2. Consistent HMI that help users to learn how to use electronic equipment, and that do not lead users to misoperations.
3. Historical module, which is used for data storage for pertinent process data or control data and for online data retrieval or archiving.

4. Computer interface, which is used for communication between the nodes of the network and the supervisory computer.
5. Vendor-created software packages for real time monitoring, control, reporting, graphics, and trending.

4.3. CIMPLICITY

The HMI package used for this project is CIMLICITY; this is a GE Fanuc Automations product. CIMPLICITY software is scalable from a Human Machine Interface to a fully networked Supervisory Control and Data Acquisition (SCADA) system. The networking capabilities inherent at all levels within the product line let the user achieve levels of integration that virtually eliminate redundant configuration within a network.

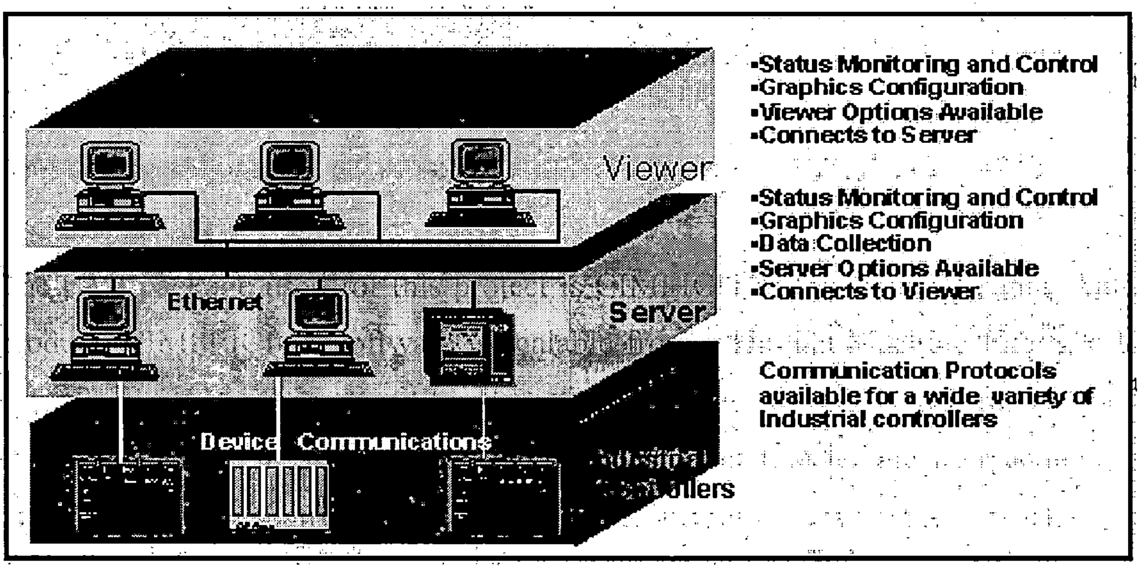


Fig 4.1. Communication Topology in CIMPLICITY

CIMPLICITY is based on a client server architecture consisting of Servers and Viewers. Servers are responsible for the collection and distribution of data. Viewers connect into Servers and have full access to the collected data. Servers and Viewers can be easily networked together to seamlessly share data without the need to replicate the point database from node to node for viewing and control actions. Servers can be licensed to collect data from, for example, 75, 150, 300, 700, 1500 or an unlimited number of device points. Exempted from the point count are virtual points, which reside only in the computer and points collected by another server.

4.4. SCREENS

The interface in CIMPLICITY is in the form of screens, this is done on CimEdit. There are number of screens and every screen has a particular function. The function of each screen is described below. The screen's layouts are shown in the Appendix 2.

4.4.1. Main Menu

This screen consists of main functions which should come in front of operator first of all after starting the project. These are as follows:

- Operations.
- Operator intervention.
- Current information.
- Reports.
- Mimic.
- Emergency.

4.4.2. Operations

The basic operations which are shown on this screen are as follows:

- Start and stop of the system.
- Status of each vibrofeeder in ADS.
- Status of cone blender.
- Status of both the conveyer belts.
- Emergency.

4.4.3. Operator Intervention

In this screen the operator on the machine can go to the load mix screen ADS.

4.4.4. Load Mix

In this screen the operator can call the require mix which was already prepared by supervisor in **Add Mix.** After selecting the mix the PC screen will be refreshed with ix details, which includes quantity of the material to feed from the respective bins, Alloy name and Lot no. of the material which should be in Bin 1 to Bin 4. PC will be asking the number of compacts required. Before selecting load button operator should confirm whether the relevant materials are present in the respective bins.

Parameters to load mix:

- Mix name and
- Number of compacts in that particular mix.

Warning:

Before load mix check various details displayed on the screen.

Confirm the availability of the various materials in the respective bin.

4.4.5. Current Information

This screen consists of some buttons which can invoke the following screens:

- Add Lot.
- Add Alloy.
- Add Mix.
- Current Status.

4.4.6. Add Lot

This screen allows only the operator to create new lot details. Various information which should be entered can be listed as.

- Lot Name.
- Impurity name.
- Amount of impurity present in ppm.

The accessibility is only to the supervisor.

4.4.7. Add Alloy

This menu allows only supervisor to create new alloy composition. Various information which can be entered are

- Alloy name (alphanumeric characters).
- Material name.
- Alloy composition in percentage (%).

The alloy details which will be set decide the compact composition.

4.4.8. Add Mix

This screen allows only supervisor to create a new mix set. The various information which should be entered by supervisor are:

- Mix name.
- Set compact weight. Set lot name of the material in Bin 1-4.(which was set in "add lot").
- Set amount of pure bulk material which should be obtained from bin 1-4.
- Set tolerance for bin 1-11.
- Set number of compacts required in the said mix.

4.4.9. Reports

This screen shows the current bin levels, mix history, lot history and alloy history.

4.4.10. Mimic

The mimic is the dynamic flow diagram of the auto dosing system. This shows the status of each of the equipment in the system by changing the colour from red to green when it goes in active state. The mimic also shows the current weight of each of the weighing pan.

All the screens show the current time and date and also the emergency button.

The development of the programme of PLC for Auto Dosing System has been simulated on a Seimen's S5 PLC with a modular approach. The simulation covers the overall sequence of the ADS and how each and every interlock affect the outputs. This program also takes care of the 2 layers and 3 layers sandwiching in the alloy compacts. The program can be implemented in the Seimen's S7 PLC, which is planned to be installed in near future for the ADS and the hydraulic press. Following are the conclusions drawn from this dissertation work

- ❖ The HMI which is created in CIMPLICITY is very much user friendly and the operator can easily follow the process and can give commands.
- ❖ The mimics which are generated gives a close real look of the ADS and the hydraulic press, from this the operator can know the status of the various parameters in the system.
- ❖ Improved technique and automation

There are others features which can be added so a lot of scope is still there for work. The future works that can be done on this system are as follows:

- ❖ To add the feature of automatic calculation of the amount of material taken from each bin.
- ❖ Make a centralized system and connect ADS to it.
- ❖ Optimization PLC programming.
- ❖ To utilize the advance features of CIMPLICITY like ALARMS, SECURITY MANAGEMENT, DYNAMIC MIMIC etc. for the improvement of the HMI.

INPUTS LISTING

Operand	Symbol	Comment
I 1.0	pb start	manual push button
I 1.2	pb stop	manual push button
I 1.3	chute B1	Proximity sensor (Inductive)
I 1.4	chute B2	Proximity sensor (I)
I 1.5	chute B3	Proximity sensor(I)
I 1.6	chute B4	Proximity sensor(I)
I 1.7	sel B1	signal from HMI to select the bin accor
I 2.0	sel B2	HMI
I 2.1	sel B3	HMI
I 2.2	sel B4	HMI
I 2.3	B1 open	Reed Switch (R.S.)
I 2.4	B1 close	R.S.
I 2.5	B2 open	R.S.
I 2.6	B2 close	R.S.
I 2.7	B3 open	R.S.
I 3.0	B3 close	R.S.
I 3.1	B4 open	R.S.
I 3.2	B4 close	R.S.
I 3.3	B1 full	Proximity(Capacitive)
I 3.4	B1 empty	Proximity(C)
I 3.5	B2 full	Proximity (I)
I 3.6	B2 empty	Proximity (I)
I 3.7	B3 full	Proximity (I)
I 4.0	B3 empty	Proximity (I)
I 4.1	B4 full	Proximity (I)

I 4.2	B4 empty	Proximity (I)
I 4.3	overload	to protect the skip hoist motor
I 4.4	hopper open	Proximity(I)
I 4.5	feedback up	raising motion of skip hoist
I 4.6	feedback dn	lowering motion of skip hoist
I 4.7	skiph LL	limit switch
I 5.0	skiph UL	limit switch
I 5.1	pb up	for lifting skip hoist
I 5.2	pb down	for lowering skip hoist
I 5.3	W1 close	R.S.
I 5.4	W1 open	R.S.
I 5.5	W2 close	R.S.
I 5.6	W2 open	R.S.
I 5.7	W1 open(m)	selector switch
I 6.0	W2 tilt(m)	selector switch
I 6.1	F1 fine(m)	selector switch
I 6.2	F1 course(m)	selector switch
I 6.3	F2 fine(m)	selector switch
I 6.4	F2 course(m)	selector switch
I 6.5	F3 fine(m)	selector switch
I 6.6	F3 course(m)	selector switch
I 6.7	F4 fine(m)	selector switch
I 7.0	F4 course(m)	selector switch
I 7.1	F5 on/off (m)	selector switch
I 7.2	FW1 on/off (m)	selector switch
I 7.3	FC on/off(m)	selector switch
I 7.4	B5 full	Proximity (I)
I 7.5	B5 empty	Proximity (I)
I 7.6	CB top	Proximity (I)
I 7.7	CB bottom	Proximity (I)
I 8.0	CB open	R.S.
I 8.1	CB close	R.S.

I 8.2	swingch up	R.S.
I 8.3	swingch dn	R.S.
I 8.4	B6 full	Proximity (I)
I 8.5	B6 empty	Proximity (I)
I 8.6	B7 full	Proximity (I)
I 8.7	B7 empty	Proximity (I)
I 9.0	F6 on/off(m)	selector switch
I 9.1	F7 on/off(m)	selector switch
I 9.2	W3 close	Proximity (I)
I 9.3	W3 open	Proximity (I)
I 9.4	B8 full	Proximity (I)
I 9.5	B8 empty	Proximity (I)
I 9.6	W4 close	Proximity (I)
I 9.7	W4 open	Proximity (I)
I 10.0	F8 on/off (m)	Proximity (I)
I 10.1	FW3on/off (m)	Proximity (I)
I 10.2	FW4on/off (m)	Proximity (I)
I 10.3	B9 full	Proximity (I)
I 10.4	B9 empty	Proximity (I)
I 10.5	B10 full	Proximity (I)
I 10.6	B10 empty	Proximity (I)
I 10.7	B11 full	Proximity (I)
I 11.0	B11 empty	Proximity (I)
I 11.1	W5 close	Proximity (I)
I 11.2	W5 open	Proximity (I)
I 11.3	F9 on/off(m)	selector switch
I 11.4	F10on/off(m)	selector switch
I 11.5	F11on/off(m)	selector switch
I 11.6	CBelt2 pos1	Proximity (I)
I 11.7	CBelt2 pos2	Proximity (I)
I 12.0	select B6	HMI

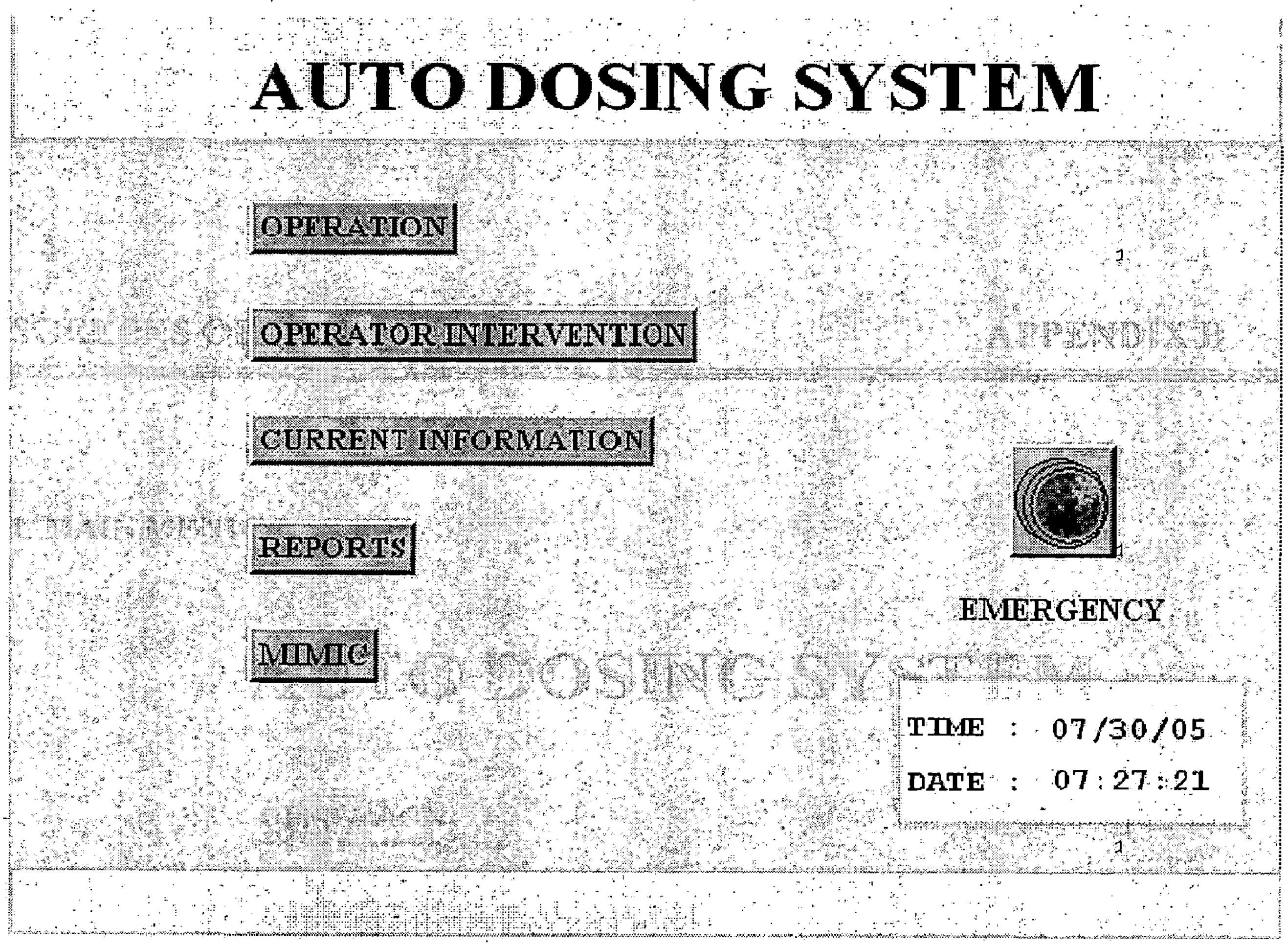
I 12.1	select B7	HMI
I 12.2	select B8	HMI
I 12.3	select B9	HMI
I 12.4	select B10	HMI
I 12.5	select B11	HMI
I 12.6	FW5on/offm	selectors switch
I 12.7	select B5	HMI
I 13.0	unused2	
I 13.1	unused3	
I 13.3	unused4	
I 13.4	unused5	
I 13.5	unused6	
I 13.6	unused7	
I 13.7	unused0	

OUTPUT LISTING

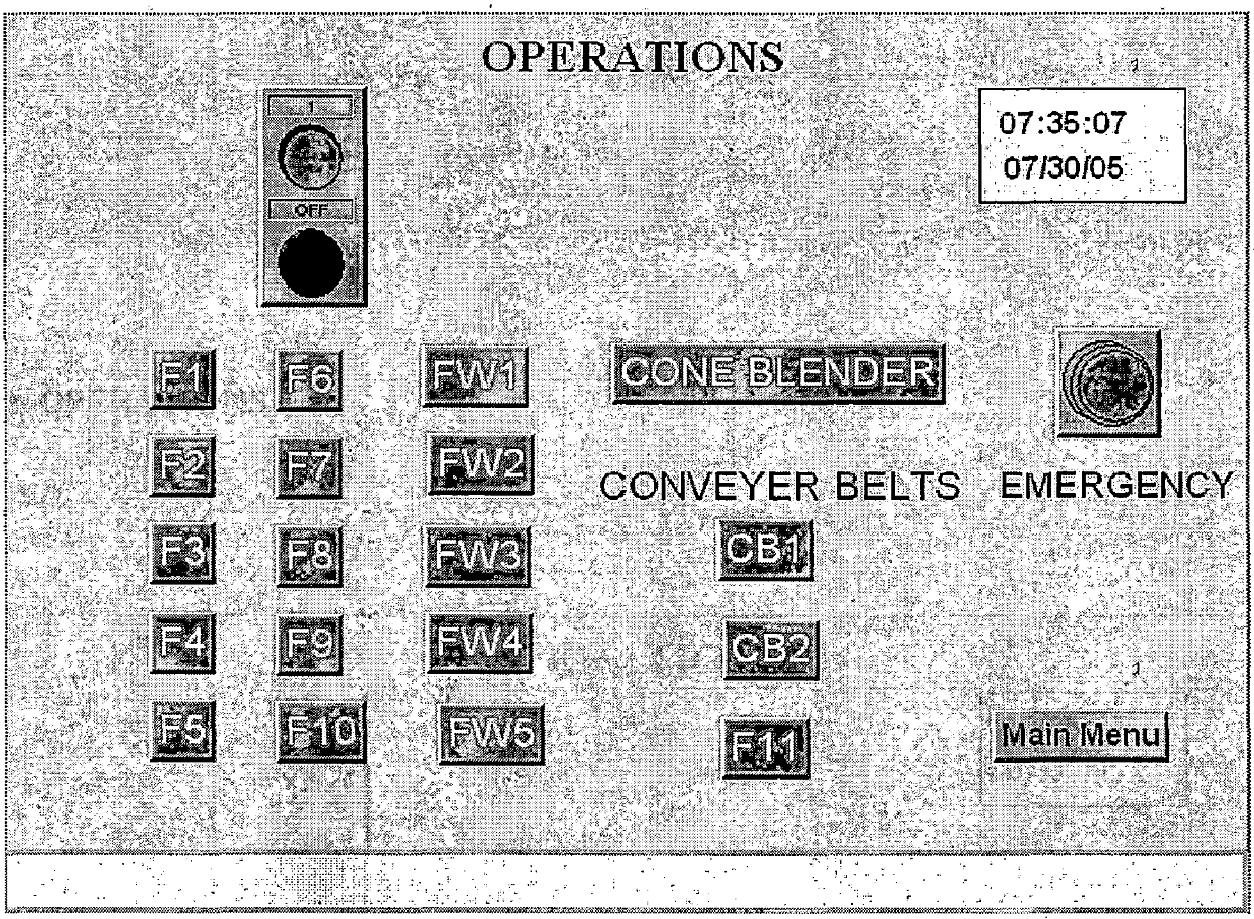
Q 14.0	Main Relay	
Q 14.1	open B1	
Q 14.2	close B1	
Q 14.3	open B2	
Q 14.4	close B2	
Q 14.5	open B3	
Q 14.6	close B3	
Q 14.7	open B4	
Q 15.0	close B4	
Q 15.1	move chute	chute motor
Q 15.2	fw up	
Q 15.3	rev dn	
Q 15.4	F1 course	
Q 15.5	F1 fine	
Q 15.6	F2 course	
Q 15.7	F2 fine	
Q 16.0	F3 course	
Q 16.1	F3 fine	
Q 16.2	F4 course	
Q 16.3	F4 fine	
Q 16.4	open W1	
Q 16.5	close W1	
Q 16.6	F5 on	
Q 16.7	up swingch	
Q 17.0	dn swingch	
Q 17.1	open CB	
Q 17.2	close CB	
Q 17.3	rotate CB	
Q 17.4	purge Ar	

Q 17.5	on FW1
Q 17.6	on F6
Q 17.7	on F7
Q 18.0	on F8
Q 18.1	on F9
Q 18.2	on F10
Q 18.3	on F11
Q 18.4	on FC
Q 18.5	on FW3
Q 18.6	on FW4
Q 18.7	on FW5
Q 19.0	on CB1
Q 19.1	pos1 CB2
Q 19.2	pos2 CB2
Q 19.3	W3 tilt
Q 19.4	W3 hori
Q 19.5	W4 tilt
Q 19.6	W4 hori
Q 19.7	W5 tilt
Q 20.0	W5 hori
Q 20.1	on CB2
Q 20.2	W2 tilt

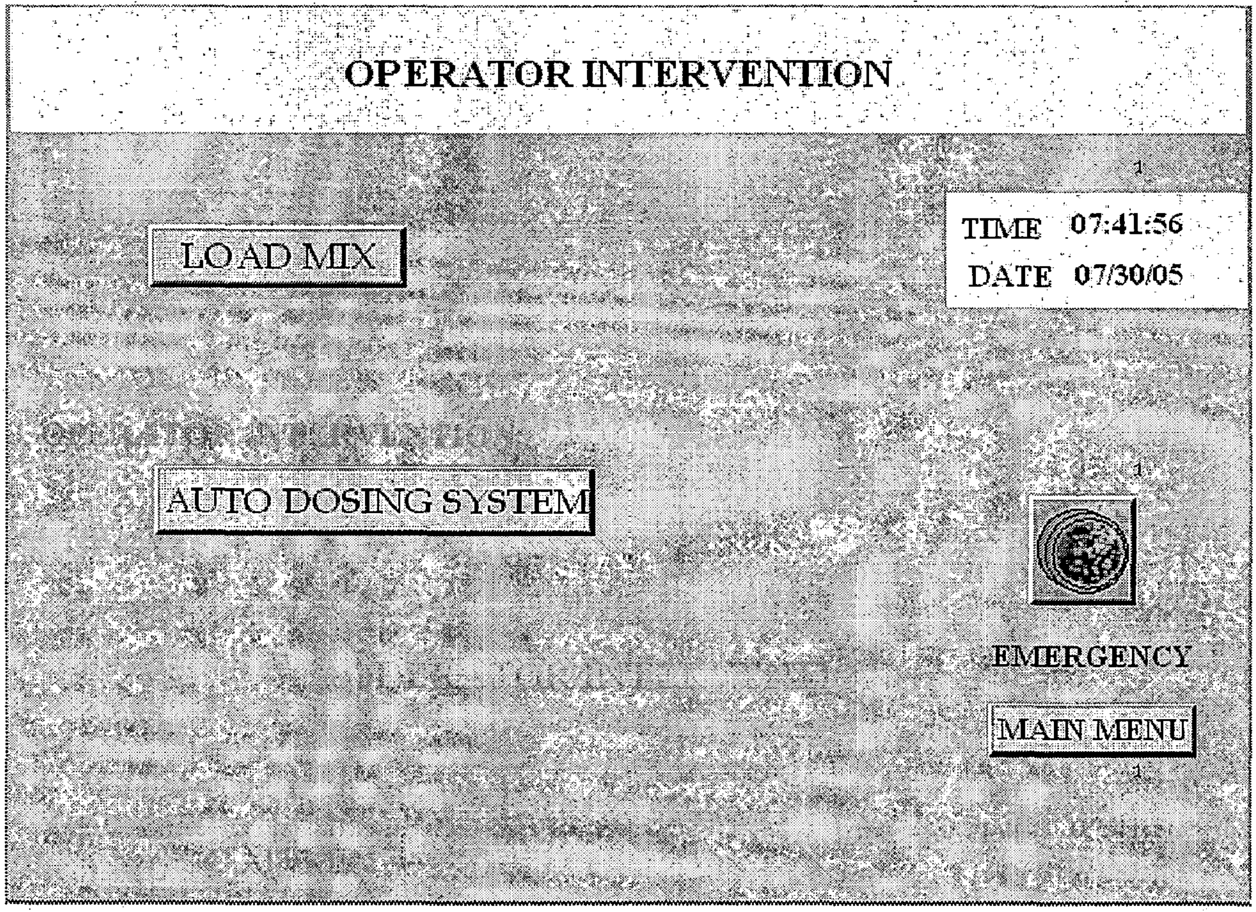
1. MAIN MENU


AUTO DOSING SYSTEM
OPERATION
OPERATOR INTERVENTION
CURRENT INFORMATION
REPORTS
MIMIC
EMERGENCY
TIME : 07/30/05
DATE : 07:27:21

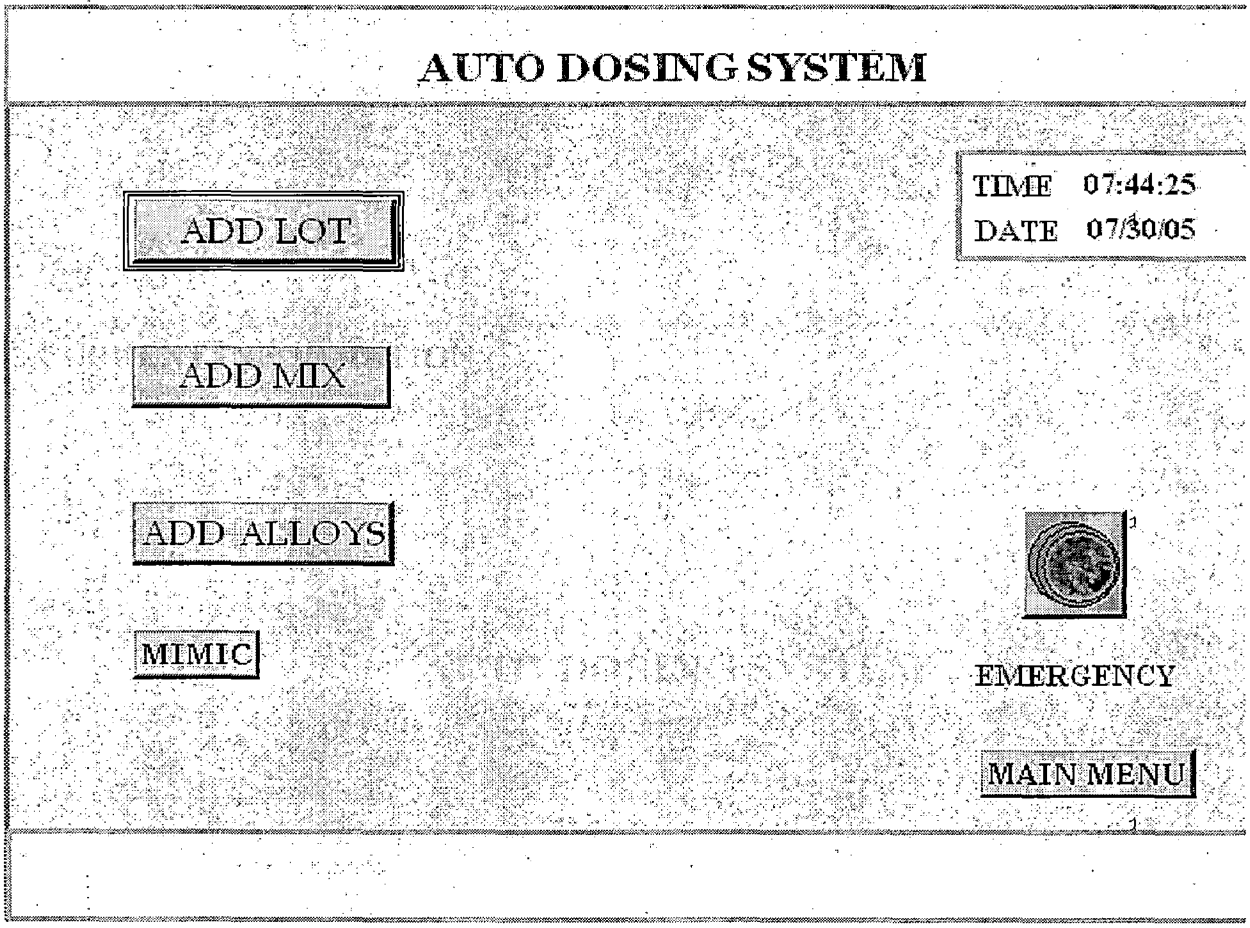
2. OPERATIONS



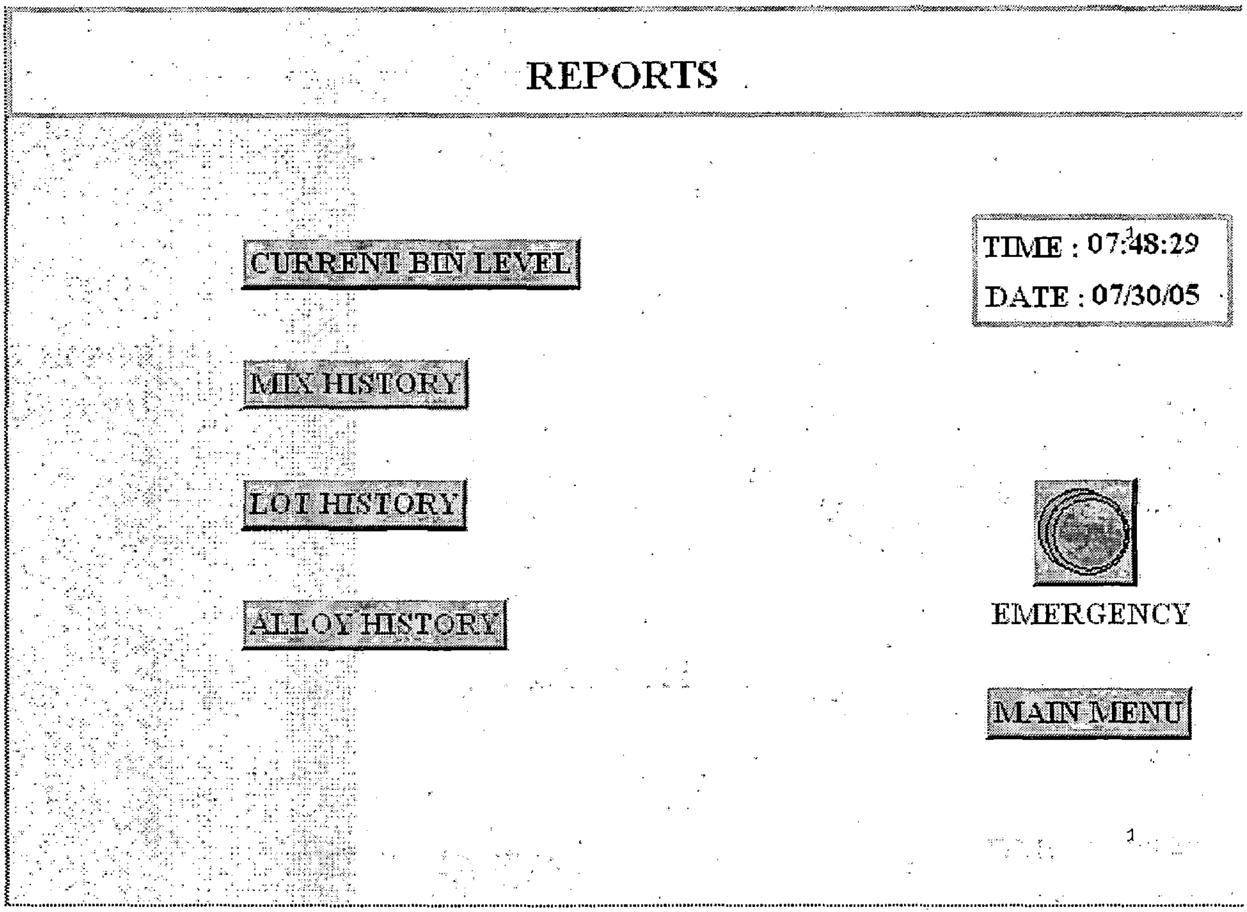
3. OPERATOR INTERVENTION



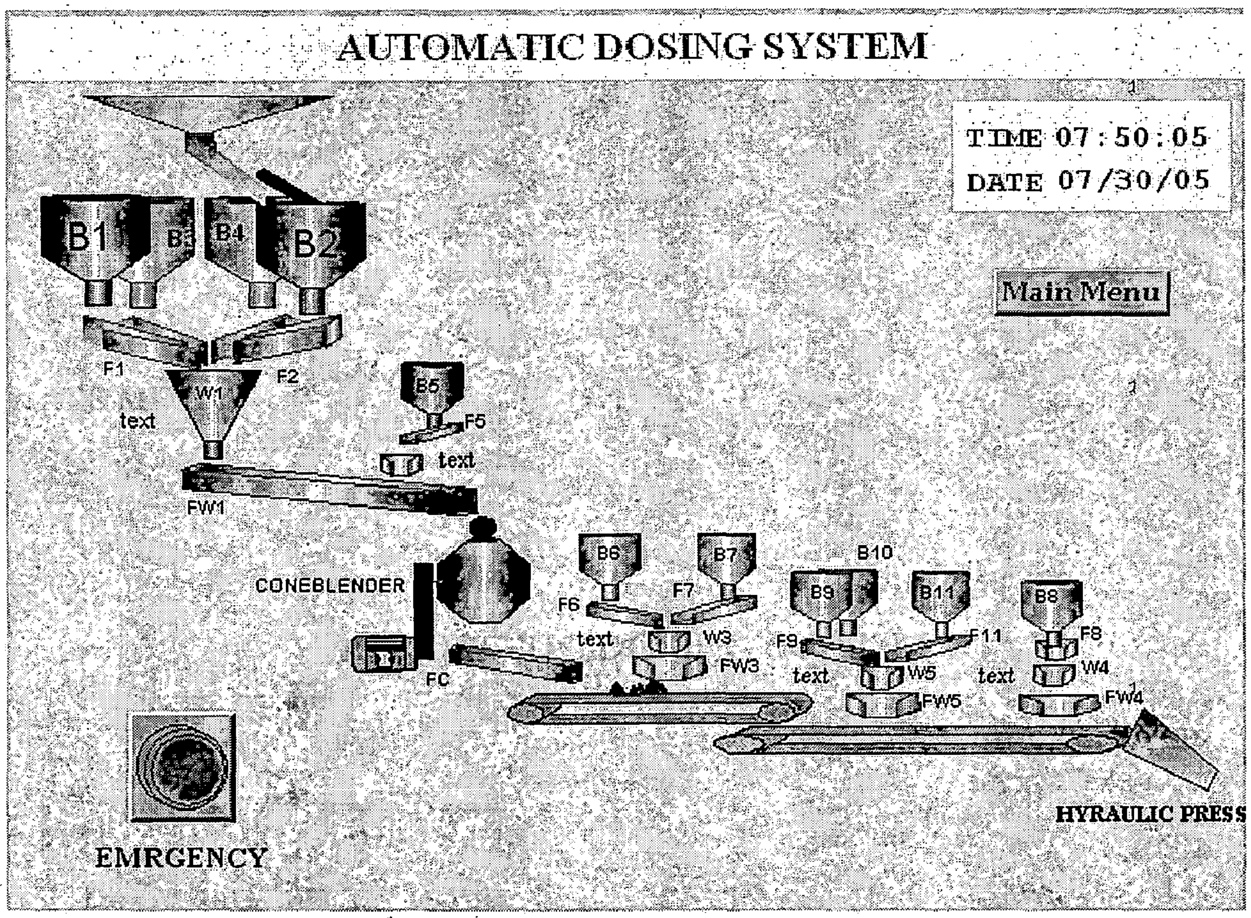
4. CURRENT INFORMATION



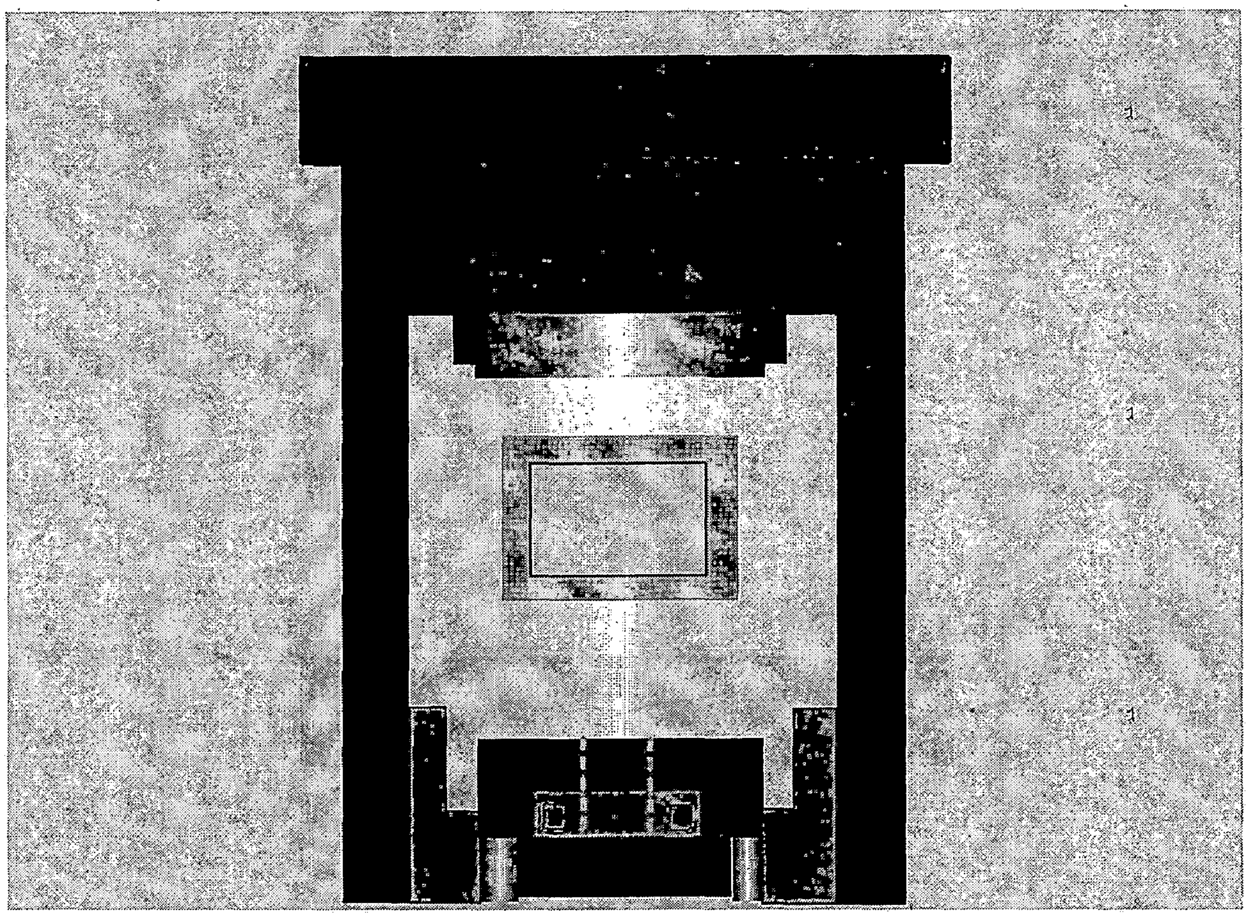
5. REPORTS


REPORTS
CURRENT BIN LEVEL
MIX HISTORY
LOT HISTORY
ALLOY HISTORY
TIME : 07:48:29
DATE : 07/30/05
EMERGENCY
MAIN MENU

6. ADS MIMIC


AUTOMATIC DOSING SYSTEM
TIME 07:50:05
DATE 07/30/05
Main Menu
B1
B3
B4
B2
F1
F2
W1
text
B5
F5
text
FW1
CONEBLENDER
FC
B6
B7
F6
F7
text
W3
FW3
B10
B9
B11
F9
F11
text
W5
FW5
B8
F8
text
W4
FW4
HYRAULIC PRESS
EMRGENCY

7. HYDRAULIC PRESS MIMIC



8. LOAD MIX

LOAD MIX

MIX NO. SELECT

PRODUCTION WEIGHT(GMS) 0

Total Sponge Wt. : text

Bin	Lot no.	Wt.(gms)	Tolerance(gms)	% Impurity
B1	NIL	0	0	0
B2	NIL	0	0	0
B3	NIL	0	0	0
B4	NIL	0	0	0

Date : text

Time : 05:30:07

Operator : name

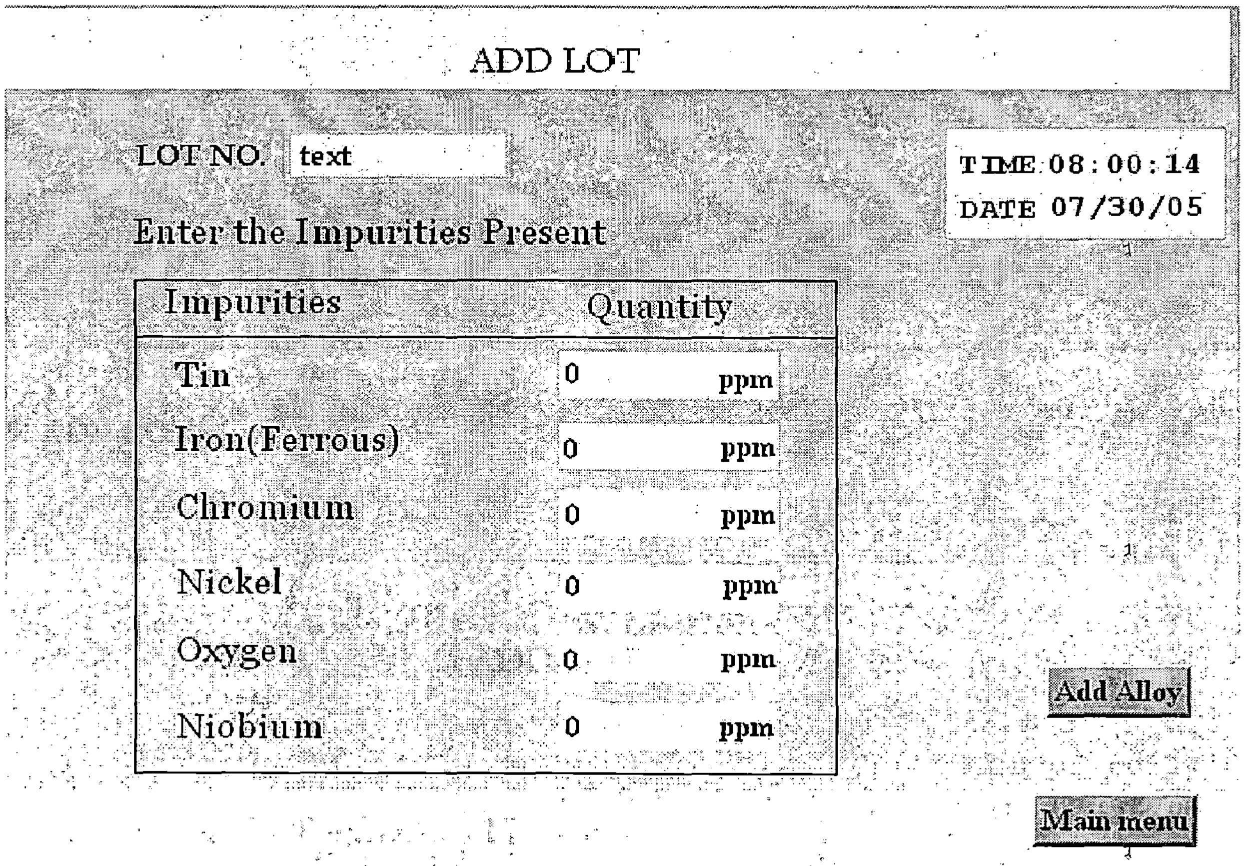
No. of compacts : text

Alloy Details	O	Nb	Sn	Fe	Cr	Ni
Required (wt%)	0	0	0.0	0.0	0.0	0.0
Wt. (B5-B11) (gms)	0	text	0	text	text	text
Tolerance(gms)	0	0	0	0	0	0

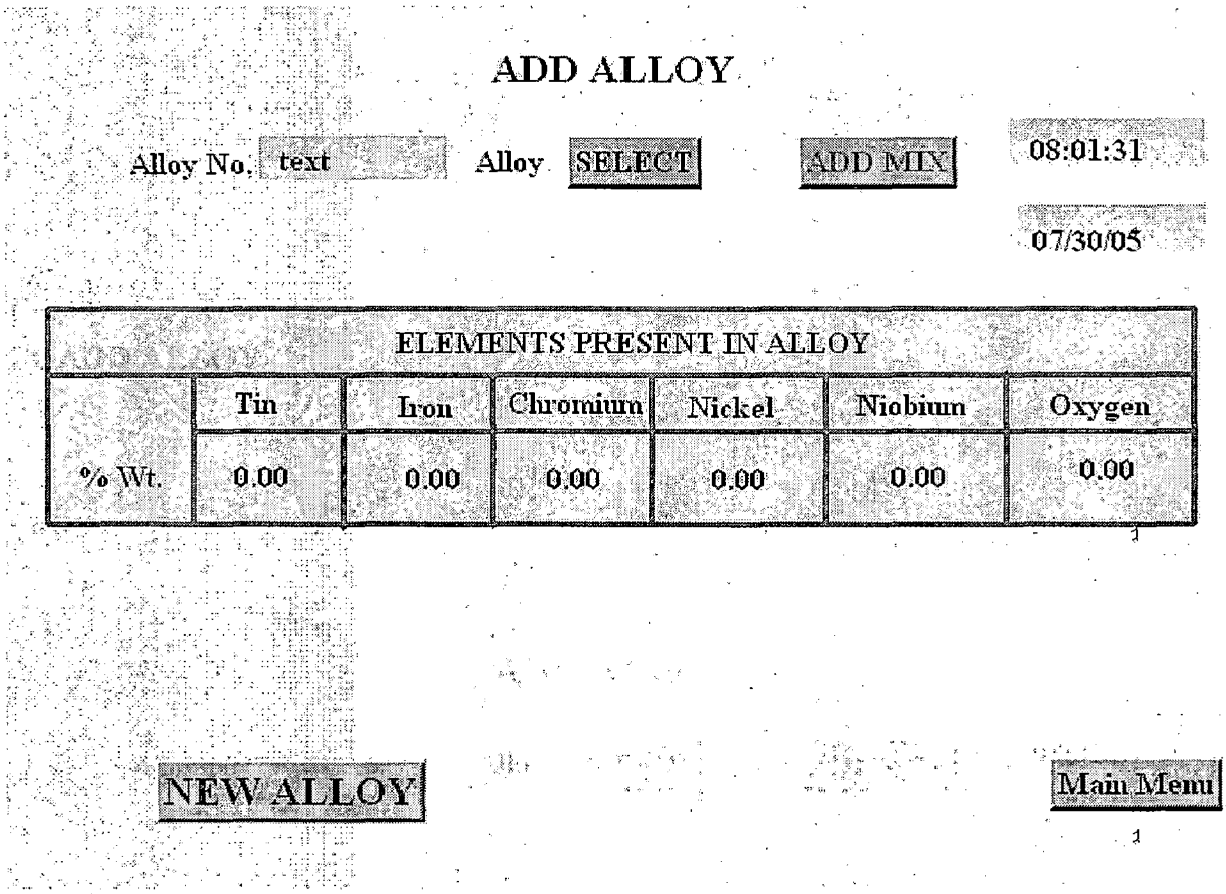
LOAD

MAIN MENU

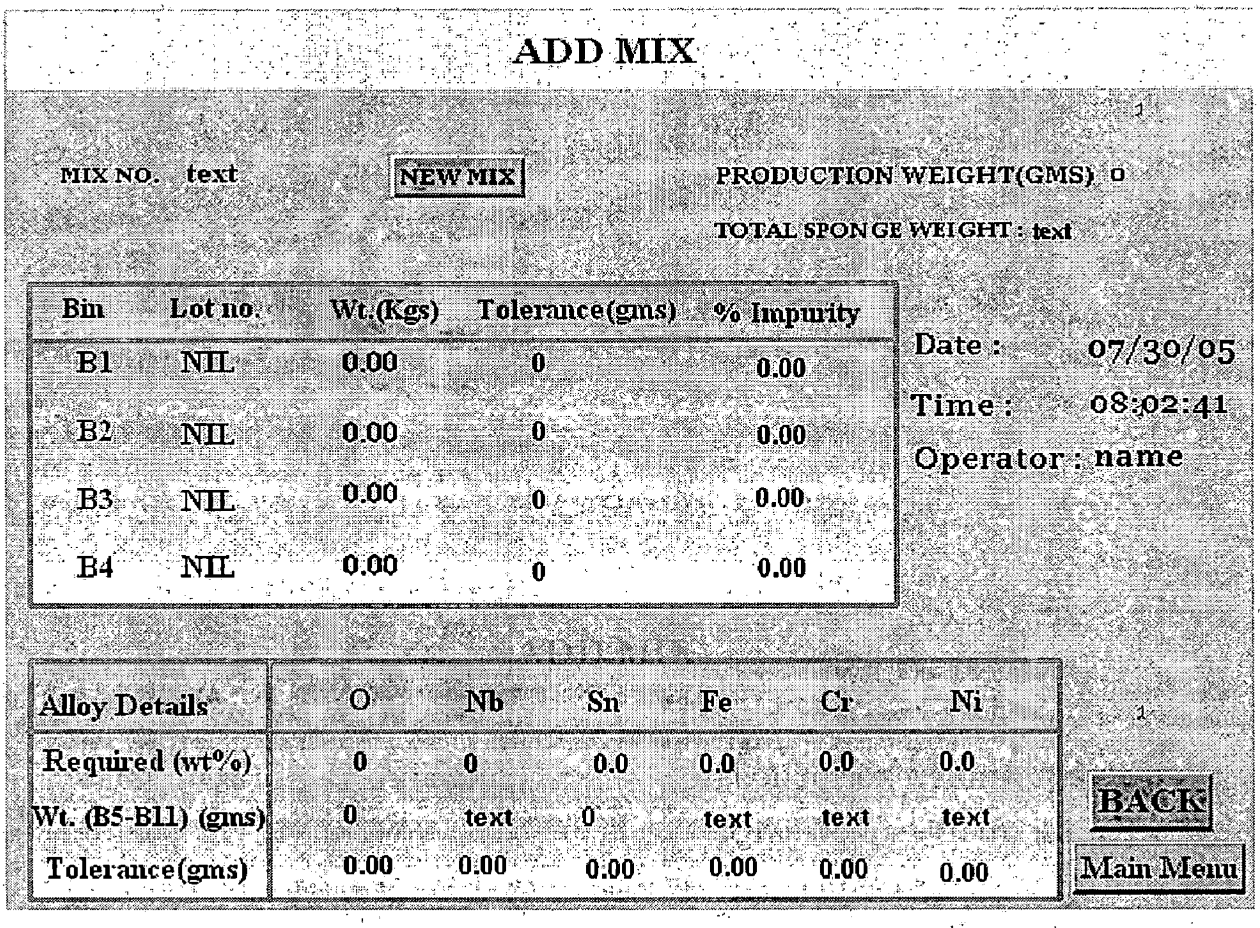
9. ADD LOT


ADD LOT
LOT NO. text
TIME 08:00:14
DATE 07/30/05
Enter the Impurities Present
Impurities
Quantity
Tin
0 ppm
Iron(Ferrous)
0 ppm
Chromium
0 ppm
Nickel
0 ppm
Oxygen
0 ppm
Niobium
0 ppm
Add Alloy
Main menu

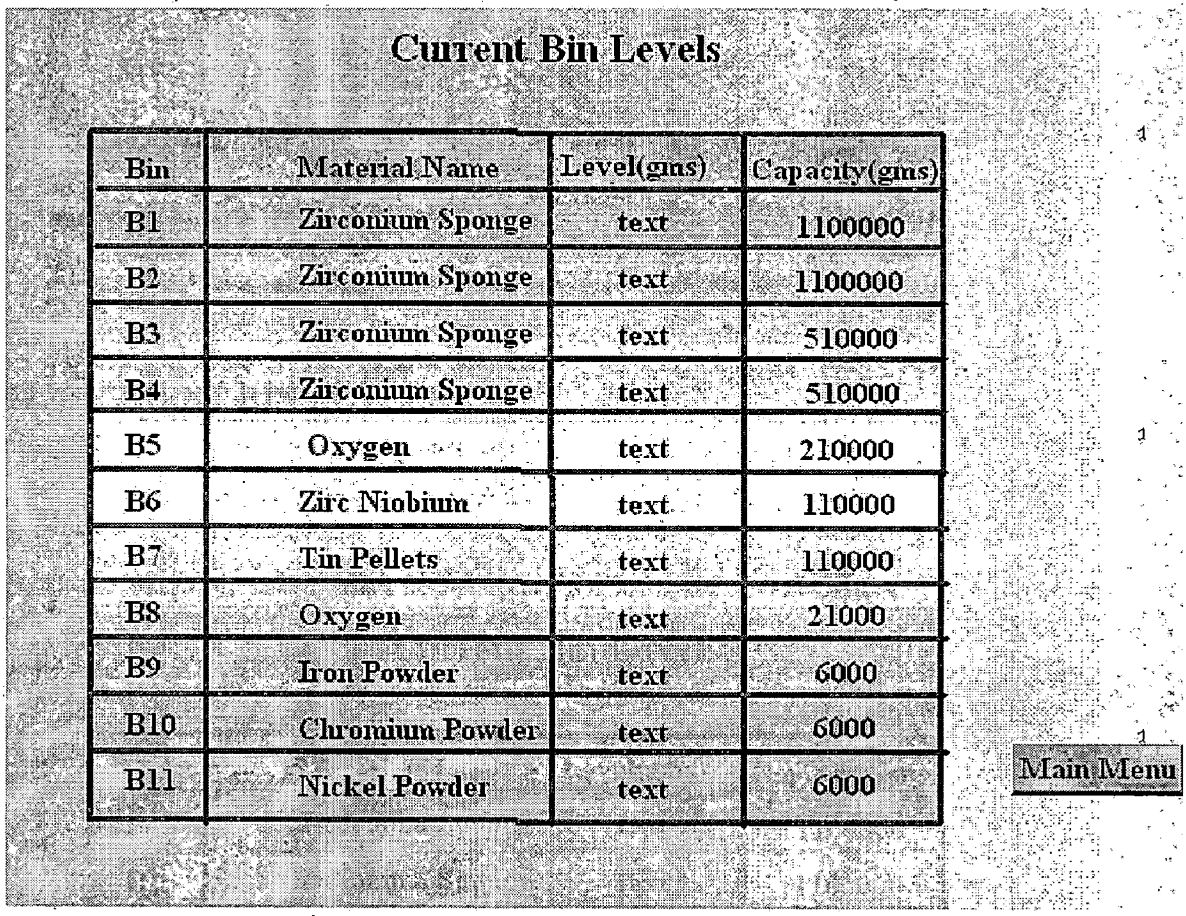
10. ADD ALLOY


ADD ALLOY
Alloy No.
text
Alloy
SELECT
ADD MIX
08:01:31
07/30/05
ELEMENTS PRESENT IN ALLOY
Tin
Iron
Chromium
Nickel
Niobium
Oxygen
% Wt.
0.00
0.00
0.00
0.00
0.00
0.00
NEW ALLOY
Main Menu

11. ADD MIX


ADD MIX
MIX NO. text
NEW MIX
PRODUCTION WEIGHT(GMS) 0
TOTAL SPONGE WEIGHT : text
Bin Lot no. Wt.(Kgs) Tolerance(gms) % Impurity
B1 NIL 0.00 0 0.00
B2 NIL 0.00 0 0.00
B3 NIL 0.00 0 0.00
B4 NIL 0.00 0 0.00
Date : 07/30/05
Time : 08:02:41
Operator : name
Alloy Details O Nb Sn Fe Cr Ni
Required (wt%) 0 0 0.0 0.0 0.0 0.0
Wt. (B5-B11) (gms) 0 text 0 text text text
Tolerance(gms) 0.00 0.00 0.00 0.00 0.00 0.00
BACK
Main Menu

12. CURRENT BIN LEVELS



Current Bin Levels

Bin	Material Name	Level(gms)	Capacity(gms)
B1	Zirconium Sponge	text	1100000
B2	Zirconium Sponge	text	1100000
B3	Zirconium Sponge	text	510000
B4	Zirconium Sponge	text	510000
B5	Oxygen	text	210000
B6	Zirc Niobium	text	110000
B7	Tin Pellets	text	110000
B8	Oxygen	text	21000
B9	Iron Powder	text	6000
B10	Chromium Powder	text	6000
B11	Nickel Powder	text	6000

Zirconium alloys are preferred for use as cladding on the fuel pallets in Pressurized Heavy Water Reactor (PHWR) and Light Water Reactors (LWR) because of the following reasons:

1. Resistant to corrosion by water at operating temperatures in such reactors.
2. The absorption cross section for the thermal neutrons of the pure metal is small.
3. Good strength at high temperatures so long life.
4. Ease of fabrication.
5. High melting point (1850° C) – structural stability at high temperature.
6. Structural stability under irradiation.

The alloys in common use as cladding material are Zircaloy-2 and Zircaloy-4, both of which have mechanical properties and corrosion resistance superior to those of zirconium itself. The alloys contain small additions of other elements to the zirconium, as follows:

	Sn	Fe	Cr	Ni
Zircaloy-2	1.5	0.15	0.10	0.05
Zircaloy-4	1.5	0.20	0.10	0.007

The PLC program is divided in seven blocks (PB1 to PB7)

```
+------------------------------------------------------------------------------+
!PROGRAM FOR AUTOMATIC DOSING SYSTEM    !                                      !
!                                       !                                      !
+------------------------------------------------------------------------------+
```

PB 1

```
Segment 1
!
!-pb start -pb stop                                                       -MR
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(   )-!
!         !
!-MR      !
+---] [---+

Segment 2
!
!-sel B1   -B1 full  -B1 close -chute B1    -MR                     -open B1
+---] [---+---]/[---+---] [---+---]/[---+---] [---+---------+---------+--(   )-!
!                   !         !
!                   !-open B1 !
!                   +---] [---+

Segment 3
!
!-sel B2   -B2 full  -B2 close -chute B2                            -open B2
+---] [---+---]/[---+---] [---+---]/[---+---------+---------+---------+--(   )-!
!                   !         !
!                   !-close B1!
!                   +---] [---+

Segment 4
!
!-sel B3   -B3 full  -B3 close -chute B3                            -open B3
+---] [---+---]/[---+---] [---+---]/[---+---------+---------+---------+--(   )-!
!                   !         !
!                   !-open B2 !
!                   +---] [---+

Segment 5
!
!-sel B4   -B4 full  -B4 close -chute B4                            -open B4
+---] [---+---]/[---+---] [---+---]/[---+---------+---------+---------+--(   )-!
!                   !         !
!                   !-close B2!
!                   +---] [---+
```

```
Segment 6
!
!-chute B1 -B1 close -sel B1                                                  -moves chu
+---] [---+---] [---+---] [---+---------+---------+---------+---------+--(    )-!
!             !             !
!-chute B1 -B1 open !       !
+---]/[---+---] [---+       !
!                           !
!-chute B2 -B2 close -sel B2 !
+---] [---+---] [---+---] [---+
!             !             !
!-chute B2 -B2 open !       !
+---]/[---+---] [---+       !
!                           !
!-chute B3 -B3 close -sel B3 !
+---] [---+---] [---+---] [---+
!             !             !
!-chute B3 -B3 open !       !
+---]/[---+---] [---+       !
!                           !
!-chute B4 -B4 close -sel B4 !
+---] [---+---] [---+---] [---+
!             !             !
!-chute B4 -B4 open !       !
+---]/[---+---] [---+       !
!                           !
!T 0                        !
+---] [---+---------+---------+
```

```
Segment 7
!
!-B1 close -sel B1                                                            F 0.5
+---] [---+---] [---+---------+---------+---------+---------+---------+--(    )-!
!                   !
!-B2 close -sel B2  !
+---] [---+---] [---+
!                   !
!-B3 close -sel B3  !
+---] [---+---] [---+
!                   !
!-B4 close -sel B4  !
+---] [---+---] [---+
```

```
Segment 8
!            T 0
!-skiph LL  +------+
+---] [---+-!T!-!S!
!KT 900.0 --!TV BI!-
!           !   DE!-
!           !     !
!F 0.5      !     !                                                           F 0.6
+---] [---+-!R   Q!-+---------+---------+---------+---------+---------+--(    )-!
!           +------+
```

```
Segment  9
!
!-hopper o -chute B1 -B1 open  -overload                                      F 0.1
+---] [---+---] [---+---] [---+---]/[---+---------+---------+---------+--(    )-!
!         !                   !
!         !-chute B2 -B2 open !
!         +---] [---+---] [---+
!         !                   !
!         !-chute B3 -B3 open !
!         +---] [---+---] [---+
!         !                   !
!         !-chute B4 -B4 open !
!         +---] [---+---] [---+
```

```
Segment 10
!
!F 0.1      -pb up      -skiph LL -feedback                                            -fw up
+---] [---+---] [---+---]/[---+---]/[---+---------+---------+---------+--(    )-!
!         !         !
!         !-fw up   !
!         +---] [---+

Segment 11
!
!F 0.1      -pb down   -skiph LL -feedback                                            -rev dn
+---] [---+---] [---+---]/[---+---]/[---+---------+---------+---------+--(    )-!
!         !         !
!         !-rev dn  !
!         +---] [---+

Segment 12
!
!-B1 open  -B1 open                                                                   -close B1
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(    )-!

Segment 13
!
!-B2 open  -chute B2                                                                  -close B2
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(    )-!

Segment 14
!
!-B3 open  -chute B3                                                                  -close B3
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(    )-!

Segment 15
!
!-B4 open  -chute B4                                                                  -close B4
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(    )-!
!
!
!                                                                                :BE
```

PB 2

```
Segment 1
!
!
!                                                                                       DB 2
+---------+---------+---------+---------+---------+---------+---------+---------+--(C   )-!
```

```
Segment 2
!
!F 0.0                                                                                  F 0.0
+---] [---+---------+---------+---------+---------+---------+---------+---------+--(    )-!
!         !
!F 0.0    !
+---]/[---+
```

```
Segment 3
!
!
!                                     FB 250
!                                    +--------------+
!                                    !   RLG:AE     !
!                    +0            --!BG        XA  !-- DW 0
!                    0,4           --!KNKT      FB  !-- F 1.2
!                    +30000        --!OGR       BU  !-- F 1.2
!                    +0            --!UGR           !
!                    F 0.0         --!EINZ          !
!                                    +--------------+
```

```
Segment 4
!
!            +-----+
!KF +10    --! --> !- DW 1
!            +-----+
```

```
Segment 5
!
!            +-----+
!DW 0      --!-   F!
!            !     !
!DW 34     --!     !- DW 35
!            +-----+
```

```
Segment 6
!
!                                     FB 243
!                                    +--------------+
!                                    !   DIV:16     !
!                    DW 2          --!Z1        OV  !-- F 1.2
!                    DW 1          --!Z2        FEH !-- F 1.2
!                                    !          Z3=0!-- F 1.1
!                                    !          Z4=0!-- F 1.2
!                                    !          Z3  !-- DW 6
!                                    !          Z4  !-- DW 7
!                                    +--------------+
```

```
Segment 7
!
!            +-----+
!KH 0008   --! --> !- DW 8
!            +-----+
```

```
Segment 8
!
!                                    FB 242
!                                  +--------------+
!                                  !   MUL:16     !
!                 DW 6           --!Z1        Z3=0!-- F 1.2
!                 DW 8           --!Z2        Z32 !-- DW 10
!                                  !          Z31 !-- DW 9
!                                  +--------------+
```

```
Segment 9
!
!              +-----+
!DW 9        --!<=  F!
!              !     !                                                      F 1.4
!DW 35       --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!              +-----+
```

```
Segment 10
!
!              +-----+
!DW 2        --!<=  F!
!              !     !                                                      F 1.5
!DW 35       --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!              +-----+
```

```
Segment 11
!
!              +-----+
!DW 2        --!-   F!
!              !     !
!DW 35       --!     !- DW 13
!              +-----+
```

```
Segment 12
!
!              +-----+
!DW 11       --!>=  F!
!              !     !                                                      F 1.7
!DW 13       --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!              +-----+
```

```
Segment 13
!
!              +-----+
!DW 2        --!+   F!
!              !     !
!DW 3        --!     !- DW 31
!              +-----+
```

```
Segment 14
!
!              +-----+
!DW 2        --!!=  F!
!              !     !                                                      F 1.6
!DW 31       --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!              +-----+
```

```
Segment 15
!
!                                  FB 243
!                                 +---------------+
!                                 !   DIV:16      !
!                   DW 31      --!Z1         OV  !-- F 1.0
!                   DW 1       --!Z2         FEH !-- F 1.0
!                                 !          Z3=0!-- F 1.0
!                                 !          Z4=0!-- F 1.0
!                                 !          Z3  !-- DW 6
!                                 !          Z4  !-- DW 7
!                                 +---------------+


Segment 16
!
!                                  FB 242
!                                 +---------------+
!                                 !   MUL:16      !
!                   DW 6       --!Z1        Z3=0!-- F 1.2
!                   DW 8       --!Z2        Z32 !-- DW 18
!                                 !          Z31 !-- DW 17
!                                 +---------------+

Segment 17
!
!             +-----+
!DW 17     --!<=   F!
!             !     !                                                      F 2.2
!DW 35     --!     Q!-+---------+---------+---------+---------+---------+--(   )-!
!             +-----+

Segment 18
!
!             +-----+
!DW 31     --!<=   F!
!             !     !                                                      F 2.3
!DW 35     --!     Q!-+---------+---------+---------+---------+---------+--(   )-!
!             +-----+

Segment 19
!
!             +-----+
!DW 31     --!-    F!
!             !     !
!DW 35     --!     !- DW 19
!             +-----+

Segment 20
!
!             +-----+
!DW 20     --!>=   F!
!             !     !                                                      F 2.4
!DW 19     --!     Q!-+---------+---------+---------+---------+---------+--(   )-!
!             +-----+

Segment 21
!
!             +-----+
!DW 31     --!+    F!
!             !     !
!DW 4      --!     !- DW 32
!             +-----+
```

Segment 22
```
!
!            +-----+
!DW 31     --!!=  F!
!            !     !                                                              F 2.5
!DW 32     --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +-----+
```

Segment 23
```
!
!                                    FB 243
!                                  +--------------+
!                                  !   DIV:16     !
!                   DW 32        --!Z1        OV  !-- F 1.0
!                   DW 1         --!Z2        FEH !-- F 1.0
!                                  !          Z3=0!-- F 1.0
!                                  !          Z4=0!-- F 1.0
!                                  !          Z3  !-- DW 6
!                                  !          Z4  !-- DW 7
!                                  +--------------+
```

Segment 24
```
!
!                                    FB 242
!                                  +--------------+
!                                  !   MUL:16     !
!                   DW 6         --!Z1        Z3=0!-- F 1.2
!                   DW 8         --!Z2        Z32 !-- DW 22
!                                  !          Z31 !-- DW 21
!                                  +--------------+
```

Segment 25
```
!
!            +-----+
!DW 21     --!<=  F!
!            !     !                                                              F 2.6
!DW 35     --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +-----+
```

Segment 26
```
!
!            +-----+
!DW 32     --!<=  F!
!            !     !                                                              F 2.7
!DW 35     --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +-----+
```

Segment 27
```
!
!            +-----+
!DW 32     --!-   F!
!            !     !
!DW 35     --!     !- DW 23
!            +-----+
```

Segment 28
```
!
!            +-----+
!DW 24     --!>=  F!
!            !     !                                                              F 3.0
!DW 23     --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +-----+
```

```
Segment 29
!
!           +-----+
!DW 32    --!+   F!
!           !     !
!DW 5     --!     !- DW 33
!           +-----+

Segment 30
!
!           +-----+
!DW 32    --!!=  F!                                                                     F 3.1
!           !     !
!DW 33    --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment 31
!
!                                     FB 243
!                                    +--------------+
!                                    !   DIV:16     !
!                   DW 33       --!Z1          OV   !-- F 1.0
!                   DW 1        --!Z2          FEH  !-- F 1.0
!                                    !         Z3=0!-- F 1.0
!                                    !         Z4=0!-- F 1.0
!                                    !         Z3   !-- DW 6
!                                    !         Z4   !-- DW 7
!                                    +--------------+

Segment 32
!
!                                     FB 242
!                                    +--------------+
!                                    !   MUL:16     !
!                   DW 6        --!Z1          Z3=0!-- F 1.2
!                   DW 8        --!Z2          Z32  !-- DW 26
!                                    !         Z31  !-- DW 25
!                                    +--------------+

Segment 33
!
!           +-----+
!DW 25    --!<=  F!                                                                     F 3.2
!           !     !
!DW 35    --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment 34
!
!           +-----+
!DW 33    --!<=  F!                                                                     F 3.3
!           !     !
!DW 35    --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment 35
!
!           +-----+
!DW 33    --!-   F!
!           !     !
!DW 35    --!     !- DW 27
!           +-----+

Segment 36
!
!           +-----+
!DW 28    --!>=  F!                                                                     F 3.4
!           !     !
!DW 27    --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+
```

Segment 37

```
     :A    -W1 open
     :L    DW   0
     :T    DW   34
     :***
```

Segment 38

```
!
!                                    FB 250
!                                  +--------------+
!                                  !    RLG:AE    !
!                    +0          --!BG         XA !-- DW 12
!                    1,4         --!KNKT       FB !-- F 1.2
!                    +1000       --!OGR        BU !-- F 1.2
!                    +0          --!UGR           !
!                    F 1.0       --!EINZ          !
!                                  +--------------+
```

Segment 39

```
!
!            +-----+
! KF +500 --! --> !- DW 14
!            +-----+
```

Segment 40

```
!
!            +-----+
!DW 12     --!-   F!
!            !     !
!DW 91     --!     !- DW 92
!            +-----+
```

Segment 41

```
!
!            +-----+
!DW 14     --!<=  F!                                                        F 2.0
!            !     !
!DW 12     --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +-----+
```

Segment 42

```
!
!            +-----+
!DW 14     --!-   F!
!            !     !
!DW 12     --!     !- DW 15
!            +-----+
```

Segment 43

```
!
!            +-----+
!KF +10    --! --> !- DW 16
!            +-----+
```

Segment 44

```
!
!            +-----+
!DW 16     --!>=  F!                                                        F 2.1
!            !     !
!DW 15     --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +-----+
```

Segment 45

```
     :A    -chute B1
     :L    DW   12
     :T    DW   91
     :BE
```

PB 3

```
Segment 1
!
!                                                                                               DB 2
+---------+---------+---------+---------+---------+---------+---------+--(C   )-!

Segment 2
!
!-W1 close    F 1.4     -sel B1    -F1 fine     T 1                 F 1.1     -F1 cours
+---] [---+---]/[---+---] [---+---]/[---+---]/[---+---------+---]/[---+--(   )-!
!         !                   !
!         !-F1 cours          !
!         +---] [---+---------+

Segment 3
!
!-W1 close F 1.5      -sel B1     F 1.4     F 1.7     T 1       F 1.1     -F1 fine
+---] [---+---]/[---+---] [---+---]/[---+---]/[---+---]/[---+---]/[---+--(   )-!
!         !                   !
!         !-F1 fine           !
!         +---] [---+---------+

Segment 6
!
!  F 1.5     F 1.7                                                          -MR
+---] [---+---]/[---+---------+---------+---------+---------+---------+--( R )-!

Segment 4
!           T 1
! F 1.5    +-----+
+---] [---+-!1_-_V!
! KT 100.0--!TV BI!-
!           !   DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+

Segment 5
!
!F 1.7     -W1 close F 2.2     -sel B2    -F2 fine     T 2       F 1.6      F 9.6
+---] [---+---] [---+---]/[---+---] [---+---]/[---+---]/[---+---]/[---+--(   )-!
!                   !                   !
!                   !-F2 fine           !
!                   +---] [---+---------+


Segment 6
!
!  F 9.6     F 6.0                                                      -F2 course
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(   )-!

Segment 7
!
!-W1 close F 2.3      -sel B2   F 2.2     F 2.4       T 2       F 1.6     -F2 fine
+---] [---+---]/[---+---] [---+---] [---+---]/[---+---]/[---+---]/[---+--(   )-!
!         !                   !
!         !-F2 fine           !
!         +---] [---+---------+
```

Segment 8

```
!             T 2
!F 2.3       +-----+
+---] [---+-!1_-_V!
!KT 100.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+
```

Segment 9

```
!
!F 2.4     -W1 close  F 2.6     -sel B3    -F3 fine    T 3       F 2.5      F 9.7
+---] [---+---] [---+---]/[---+---] [---+---]/[---+---]/[---+---]/[---+--(   )-!
!                   !                    !
!                   !-F3 cours           !
!                   +---] [---+---------+
```

Segment 10

```
!
!  F 9.7     F 6.0                                                  -F3 cours
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(   )-!
```

Segment 11

```
!
!-W1 close   F 2.7   -sel B3     F 2.6     F 3.0      T 3      F 2.5      -F3 fine
+---] [---+---]/[---+---] [---+---] [---+---]/[---+---]/[---+---]/[---+--(   )-!
!         !                   !
!         !-F3 fine           !
!         +---] [---+---------+
```

Segment 12

```
!             T 3
!F 2.7       +-----+
+---] [---+-!1_-_V!
!KT 100.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+
```

Segment 13

```
!
!F 3.0     -W1 close F 3.2     -sel B4    -F4 fine    T 4       F 3.1      F 8.1
+---] [---+---] [---+---]/[---+---] [---+---]/[---+---]/[---+---]/[---+--(   )-!
!                   !                    !
!                   !-F4 cours           !
!                   +---] [---+---------+
```

Segment 14

```
!
!F 8.1     F 6.0                                                      -F4 cours
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(   )-!
```

Segment 15

```
!
!-W1 close  F 3.3     -sel B4   F 2.6     F 3.4     T 4       F 3.1      -F4 fine
+---] [---+---]/[---+---] [---+---] [---+---]/[---+---]/[---+---]/[---+--(   )-!
!         !                   !
!         !-F4 fine           !
!         +---] [---+---------+
```

Segment 16
```
!                 T 4
!F 3.3          +-----+
+---] [---+-!1_-_V!
!KT 100.0 --!TV BI!-
!           !    DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+
```

Segment 17
```
!
!F 3.4      F 3.0      F 2.4      F 1.7      T 1                                             -open W1
+---] [---+---] [---+---] [---+---] [---+---] [---+---------+---------+--(   )-!
!                                         !          !
!                                         !T 2       !
!                                         +---] [---+
!                                         !          !
!                                         !T 3       !
!                                         +---] [---+
!                                         !          !
!                                         !T 4       !
!                                         +---] [---+
```

Segment 18
```
!-B5 empty -W2 close   F 2.0      -sel B5   F 2.1                                            -F5 on
+---] [---+---] [---+---]/[---+---] [---+---]/[---+---------+---------+--(   )-!
!                   !                   !
!                   !-F5 on             !
!                   +---] [---+---------+
```

Segment 19
```
!
!-CB top    -CB close                                                                      -up swing
+---] [---+---] [---+---------+---------+---------+---------+---------+--(   )-!
!                   !
!T 6                !
+---] [---+---------+
```

Segment 20
```
!
!-CB top    -swich up   -CB close                                                          -open CB
+---] [---+---] [---+---] [---+---------+---------+---------+---------+--(   )-!
!                             !
!   F8.1     -CB bott         !
+---] [---+---] [---+---------+
```

Segment 21
```
!
!-CB open   -swing dn   -CB top      T 6                                                   -on FW1
+---] [---+---] [---+---] [---+---]/[---+---------+---------+---------+--(   )-!
```

Segment 22
```
!
!-sel B5     F 2.1      -on FW1                                                            -W2 tilt
+---] [---+---] [---+---] [---+---------+---------+---------+---------+--(   )-!
```

Segment 23
```
!
!-CB open    -CB top    -swing  dn                                                          F 9.1
+---] [---+---] [---+---] [---+---------+---------+---------+---------+--(   )-!
```

```
Segment 24
!             T 6
!F 9.1       +------+
+---] [---+-!T!-!0!
!KT 100.1 --!TV BI!-
!            !   DE!-
!            !     !
!            !     !
!         +-!R    Q!-
!            +------+
```

```
Segment 25
!
!T 6        -swing up                                                         -close CB
+---] [---+---] [---+---------+---------+---------+---------+---------+--(    )-!
!                   !
!T 8                !
+---] [---+---------+
```

```
Segment 26
!
!-CB top   -swing up                 F 8.1     T 7                              CB rotat
+---] [---+---] [---+---------+---]/[---+---] [---+---------+---------+--(    )-!
!                                                 !
!-swing up     T 8      -CB close  -CB top        !
+---] [---+---] [---+---] [---+---]/[---+---------+
```

```
Segment 27
!
!F 0.0                                                                        F 0.0
+---] [---+---------+---------+---------+---------+---------+---------+--(    )-!
!         !
!F 0.0    !
+---]/[---+
```

```
Segment 28

     :A    F     0.0
     :L    KC 003
     :S    C     1
     :L    C     1
     :T    FW   60
     :A    -CB bottom
     :CU   C     1
     :A    C     1
     :=    F     0.1
     :A    -CB open
     :R    C     1
     :***
```

```
Segment 29
!
!            +------+
!FW 60     --!!=   F!
!            !      !                                                        F 8.1
!KF +3     --!     Q!-+---------+---------+---------+---------+---------+--(    )-!
!            +------+
```

```
Segment 30
!
! T 6       -CB top   -CB close                                                 F 9.2
+---] [---+---] [---+---] [---+---------+---------+---------+---------+--(    )-!
!                                                                       !        !
!                                                                       !-purge Ar
!                                                                       +--(    )-!
```

```
Segment 31
!                  T 7
!F 9.2          +-----+
+---] [---+-!T!-!0!
!KT 100.1 --!TV  BI!-
!             !     DE!-
!             !       !
!             !       !
!          +-!R     Q!-
!             +-----+
```

```
Segment 32
!
!-CB open   -CB bott                                                              F 9.3
+---] [---+---] [---+---------+---------+---------+---------+---------+--(    )-!
```

```
Segment 33
!                  T 8
!F 9.3          +-----+
+---] [---+-!T!-!0!
!KT 100.1 --!TV  BI!-
!             !     DE!-
!             !       !
!             !       !
!          +-!R     Q!-
!             +-----+
```

```
Segment 34
     :A    F     0.0
     :L    DW   64
     :S    C     2
     :L    C     2
     :T    FW   25
     :A    -W1 close
     :CU   C     2
     :A    C     2
     :=    F     0.2
     :A    F     0.3
     :R    C     3
     :***
```

```
Segment 35
!
!             +-----+
!FW 25     --!!=   F!
!             !       !                                                   F 6.0
!DW 64     --!     Q!-+---------+---------+---------+---------+---------+--(    )-!
!             +-----+
!
!                                                                          :BE
```

PB 4

```
Segment 1
!
!                                                                        DB 2
+---------+---------+---------+---------+---------+---------+---------+--(C  )-!


Segment 2
!
!                                 FB 250
!                                +--------------+
!                                !    RLG:AE    !
!                 +0           --!BG          XA!-- DW 40
!                 2,4          --!KNKT        FB!-- F 1.2
!                 +1500        --!OGR         BU!-- F 1.2
!                 +0           --!UGR           !
!                 F 1.0        --!EINZ          !
!                                +--------------+


Segment 3
!
!          +-----+
!DW 41   --!<=  F!
!          !     !                                                       F 4.0
!DW 40   --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!          +-----+


Segment 4
!
!          +-----+
!DW 41   --!-   F!
!          !     !
!DW 40   --!     !- DW 42
!          +-----+


Segment 5
!
!          +-----+
!DW 42   --!<=  F!
!          !     !                                                       F 4.1
!DW 43   --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!          +-----+


Segment 6
!
!          +-----+
!DW 45   --!<=  F!
!          !     !                                                       F 4.2
!DW 40   --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!          +-----+


Segment 7
!
!          +-----+
!DW 45   --!-   F!
!          !     !
!DW 40   --!     !- DW 46
!          +-----+


Segment 8
!
!          +-----+
!DW 47   --!<=  F!
!          !     !                                                       F 4.3
!DW 46   --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!          +-----+
```

```
Segment 9
!
! -W3 close  -select B F 4.0      -on F7     -B6 empty             F 4.1     -on F6
+---] [---+---] [---+---]/[---+---]/[---+---]/[---+---------+---]/[---+--(    )-!
!         !                   !
!         !  -on F6           !
!         +---] [---+---------+

Segment 10
!
!-on F6    -select B    F 9.2      -W3 close -B7 empty             F 4.3      -on F7
+---]/[---+---] [---+---]/[---+---] [---+---]/[---+---------+---]/[---+--(    )-!
!         !                   !
!         !  -on F6           !
!         +---] [---+---------+

Segment 11
!
!F 4.1     -on F6     -on F7                                          -W3 tilt
+---] [---+---]/[---+---]/[---+---------+---------+---------+---------+--(    )-!
!         !
! F 4.3   !
+---] [---+

Segment 12
!          T 19
!-W3 tilt   +------+
+---] [---+-!T!-!0!
!KT 500.0 --!TV BI!-
!           !    DE!-
!           !      !
!           !      !
!         +-!R    Q!-
!           +------+

Segment 13
!
!T 19                                                                   -W3 hori
+---] [---+---------+---------+---------+---------+---------+---------+--(    )-!
!
!
!                                                                      :BE
```

PB 5

```
Segment 1
!
!                                                                                 DB 2
+---------+---------+---------+---------+---------+---------+---------+--(C  )-!

Segment 2
!
!                                       FB 250
!                                        +--------------+
!                                        !   RLG:AE     !
!                  +0                 --!BG          XA !-- DW 59
!                  3,4                --!KNKT        FB !-- F 1.2
!                  +1000              --!OGR         BU !-- F 1.2
!                  +0                 --!UGR            !
!                  F 1.0              --!EINZ           !
!                                        +--------------+

Segment 3
!
!           +-----+
!DW 60    --!<=  F!
!           !     !                                                            F 5.2
!DW 59    --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!           +-----+

Segment 4
!
!           +-----+
!DW 60    --!-   F!
!           !     !
!DW 59    --!     !- DW 61
!           +-----+

Segment 5
!
!           +-----+
!DW 61    --!<=  F!
!           !     !                                                          F 5.3
!DW 62    --!    Q!-+---------+---------+---------+---------+---------+--(    )-!
!           +-----+

Segment 6
!
!-W4 close -sel B8     F 5.2     -B8 empty          F 5.3                -on F8
+---] [---+---] [---+---]/[---+---]/[---+---------+---]/[---+---------+--(    )-!
!         !                   !
!         !  -on F8           !
!         +---] [---+---------+

Segment 7
!
!F 5.3     -on F8                                                          -W4 tilt
+---] [---+---]/[---+---------+---------+---------+---------+---------+--(    )-!

Segment 8
!           T 20
!-W4 tilt    +-----+
+---] [---+-!T!-!0!
!KT 500.0 --!TV BI!-
!           !   DE!-
!           !     !
!         +-!R   Q!-
!            +-----+

Segment 9
!
!T 20                                                                      -W4 hori
+---] [---+---------+---------+---------+---------+---------+---------+--(    )-!
!
!
!                                                                         :BE
```

PB 6

```
Segment 1
!
!                                                                                                    DB 2
+---------+---------+---------+---------+---------+---------+---------+--(C  )-!
```

```
Segment 2
!
!                                          FB 250
!                                        +---------------+
!                                        !    RLG:AE     !
!                        +0          --!BG          XA  !-- DW 49
!                        4,4         --!KNKT        FB  !-- F 1.2
!                        +1000       --!OGR         BU  !-- F 1.2
!                        +0          --!UGR             !
!                        F 1.0       --!EINZ            !
!                                        +---------------+
```

```
Segment  3
!
!              +-----+
!DW 49     --!-    F!
!              !     !
!DW 95     --!     !- DW 96
!              +-----+
```

```
Segment  4
!
!              +-----+
!DW 50     --!<=   F!
!              !     !                                                          F 4.4
!DW 96     --!     Q!-+---------+---------+---------+---------+---------+--(  )-!
!              +-----+
```

```
Segment  5
!
!              +-----+
!DW 50     --!-    F!
!              !     !
!DW 96     --!     !- DW 51
!              +-----+
```

```
Segment  6
!
!              +-----+
!DW 51     --!<=   F!
!              !     !                                                          F 4.5
!DW 52     --!     Q!-+---------+---------+---------+---------+---------+--(  )-!
!              +-----+
```

```
Segment  7
!
!              +-----+
!DW 50     --!+    F!
!              !     !
!DW 53     --!     !- DW 70
!              +-----+
```

```
Segment  8
!
!              +-----+
!DW 70     --!<=   F!
!              !     !                                                          F 4.6
!DW 96     --!     Q!-+---------+---------+---------+---------+---------+--(  )-!
!              +-----+
```

```
Segment  9
!
!          +-----+
!DW 70   --!-   F!
!          !     !
!DW 96   --!     !- DW 54
!          +-----+

Segment  10
!
!          +-----+
!DW 54   --!<=  F!
!          !     !                                                          F 4.7
!DW 55   --!    Q!-+---------+---------+---------+---------+---------+--(     )-!
!          +-----+

Segment  11
!
!          +-----+
!DW 70   --!+   F!
!          !     !
!DW 56   --!     !- DW 71
!          +-----+

Segment  12
!
!          +-----+
!DW 71   --!<=  F!
!          !     !                                                          F 5.0
!DW 96   --!    Q!-+---------+---------+---------+---------+---------+--(     )-!
!          +-----+


Segment  13
!
!          +-----+
!DW 71   --!-   F!
!          !     !
!DW 96   --!     !- DW 57
!          +-----+

Segment  14
!
!          +-----+
!DW 57   --!<=  F!
!          !     !                                                          F 5.1
!DW 58   --!    Q!-+---------+---------+---------+---------+---------+--(     )-!
!          +-----+

Segment  15
     :A    -W5 open
     :L    DW  96
     :T    DW  94
     :***


Segment  16
!
!-W5 close  -sel B9     F 4.4     -B9 empty   T 13       F 4.5              -on F9
+---] [---+---] [---+---]/[---+---]/[---+---]/[---+---]/[---+---------+--(     )-!
!         !                   !
!         !  -on F9           !
!         +---] [---+---------+
```

```
Segment  17
!
!F 4.5   -W5 close  -sel B10   F 4.6     -B10 empt   T 14     F 4.7    -on F10
+---] [---+---] [---+---] [---+---]/[---+---]/[---+---]/[---+---]/[---+--(   )-!
!                   !                   !
!                   !  -on F10          !
!                   +---] [---+---------+

Segment  18
!
!F 4.7     -W5 close  -sel B11  F 5.0    -B11 empt   T 15      F 5.1    -on F11
+---] [---+---] [---+---] [---+---]/[---+---]/[---+---]/[---+---]/[---+--(   )-!
!         !                   !
!         !  -on F6           !
!         +---] [---+---------+

Segment  19
!
!F 5.1     -on F9    -on F10   -on F11                                 -W5 tilt
+---] [---+---]/[---+---]/[---+---]/[---+---------+---------+---------+--(   )-!


Segment  20
!          T 13
!F 4.4      +-----+
+---] [---+-!1_-_V!
!KT 050.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+

Segment  21
!          T 14
!F 4.6      +-----+
+---] [---+-!1_-_V!
!KT 050.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+

Segment  22
!          T 15
!F 5.0      +-----+
+---] [---+-!1_-_V!
!KT 050.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !
!         +-!R   Q!-
!           +-----+

Segment  23
!          T 16
!-W5 tilt   +-----+
+---] [---+-!T!-!0!
!KT 050.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !                                                F 8.1
!         +-!R   Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment  24
!
!T 16                                                              -W5 hori
+---] [---+---------+---------+---------+---------+---------+---------+--(   )-!
!
!
!                                                                :BE
```

PB 7

```
Segment  1
!
!                                                                                   DB 2
+---------+---------+---------+---------+---------+---------+---------+--(C  )-!

Segment  2
!
!F 9.7     -CB2 pos1 -on CB1                                                  -pos2 CB2
+---] [---+---] [---+---]/[---+---------+---------+---------+---------+--(   )-!
!         !         !
!         !-CB2 pos2!
!         +---]/[---+

Segment  3
!
!-CB2 pos2 -CB bott  -CB open                                                  -on CB2
+---] [---+---] [---+---] [---+---------+---------+---------+---------+--(   )-!
!         !                   !
!         !-on CB2            !
!         +---] [---+---------+

Segment  4
!
! -on CB2                                                                      -on CB1
+---] [---+---------+---------+---------+---------+---------+---------+--(   )-!

Segment 5
!
!                                   FB 243
!                                    +--------------+
!                                    !   DIV:16     !
!                         DW 66    --!Z1        OV  !-- F 1.0
!                         DW 68    --!Z2        FEH !-- F 1.0
!                                    !          Z3=0!-- F 1.1
!                                    !          Z4=0!-- F 1.1
!                                    !          Z3  !-- DW 67
!                                    !          Z4  !-- DW 69
!                                    +--------------+

Segment 6
!
!                                   FB 241
!                                    +--------------+
!                                    !   COD:16     !
!                         DW 67    --!DUAL      SBCD!-- F 1.2
!                                    !          BCD2!-- DR 200
!                                    !          BCD1!-- DW 72
!                                    +--------------+

Segment 7
!
!                                   FB 1
!                                    +--------------+
!                                    !   TIMEBASE   !
!                                    +--------------+

Segment 8
!
!F 0.0                                                                         F 0.0
+---] [---+---------+---------+---------+---------+---------+---------+--(   )-!
!         !
!F 0.0    !
+---]/[---+
```

```
Segment   9
!
!-CB botto -CB open                                                      F 5.5
+---] [---+---] [---+---------+---------+---------+---------+---------+--(   )-!

Segment  10
     :A    F     0.0
     :L    DW   68
     :S    C     3
     :L    C     3
     :T    FW   21
     :A    -on  FC
     :CU   C     3
     :A    C     3
     :=    F     0.1
     :A    F     5.5
     :R    C     3
     :***

Segment  11
!
!           +-----+
!FW 21    --!>=  F!
!           !     !                                                      F 6.4
!DW 68    --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment  12
!
!F 6.1      -on CB1    -on CB2    F 6.4                                 F 6.3
+---]/[---+---] [---+---] [---+---]/[---+---------+---------+---------+--(   )-!

Segment  13
!           T 17
!F 6.3      +-----+
+---] [---+-!1_-_V!
!DW 74    --!TV BI!-
!           !   DE!-
!           !     !
!           !     !                                                      -on FC
!         +-!R   Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment  14
!           T 18
!-on FC     +-----+
+---]/[---+-!1_-_V!
!KT 900.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !                                                      F 6.1
!         +-!R   Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment  15
!           T 21
!-on CB1    +-----+
+---] [---+-!T!-!0!
!KT 400.0 --!TV BI!-
!           !   DE!-
!           !     !
!           !     !                                                      F 6.7
!         +-!R   Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment  16
!
!           +-----+
!DW 68    --!-   F!
!           !     !
!KF +1    --!     !- DW 91
!           +-----+
```

```
Segment  17
!
!                                    FB 243
!                                  +--------------+
!                                  !   DIV:16     !
!                       DW 75    --!Z1       OV   !-- F 1.2
!                       DW 91    --!Z2       FEH  !-- F 1.2
!                                  !         Z3=0 !-- F 1.2
!                                  !         Z4=0 !-- F 1.2
!                                  !         Z3   !-- DW 76
!                                  !         Z4   !-- DW 77
!                                  +--------------+
Segment  18
!
!                                     FB 241
!                                  +--------------+
!                                  !   COD:16     !
!                       DW 76    --!DUAL     SBCD!-- F 1.2
!                                  !         BCD2!-- DR 201
!                                  !         BCD1!-- DW 78
!                                  +--------------+
Segment  19
!
!                                       FB 2
!                                  +--------------+
!                                  !   TIMEB2     !
!                                  +--------------+

Segment  20
!
!F 7.2      F 6.7      F 7.0                                                            F 7.1
+---]/[---+---] [---+---]/[---+---------+---------+---------+---------+--(   )-!
Segment  21
!
!          +-----+
!FW 21    --!>=  F!
!          !     !                                                                   F 7.0
!DW 91    --!    Q!-+---------+---------+---------+---------+---------+--(   )-!
!          +-----+

Segment  22
!          T 22
!F 7.1     +-----+
+---] [---+-!1_-_V!
!DW 79    --!TV BI!-
!          !   DE!-
!          !     !
!          !     !                                                                -on FW3
!        +-!R   Q!-+---------+---------+---------+---------+---------+--(   )-!
!          +-----+
Segment  23
!        T 23
!-on FW3   +-----+
+---]/[---+-!1_-_V!
!KT 100.1 --!TV BI!-
!          !   DE!-
!          !     !
!          !     !                                                                   F 7.2
!        +-!R   Q!-+---------+---------+---------+---------+---------+--(   )-!
!          +-----+

Segment  24
!
!                                 FB 243
!                                  +--------------+
!                                  !   DIV:16     !
!                       DW 81    --!Z1       OV   !-- F 1.2
!                       DW 91    --!Z2       FEH  !-- F 1.2
!                                  !         Z3=0 !-- F 1.2
!                                  !         Z4=0 !-- F 1.2
!                                  !         Z3   !-- DW 82
!                                  !         Z4   !-- DW 83
!                                  +--------------+
```

```
Segment  25
!
!                                  FB 241
!                                 +--------------+
!                                 !   COD:16     !
!                     DW 82     --!DUAL      SBCD!-- F 1.2
!                                 !          BCD2!-- DR 202
!                                 !          BCD1!-- DW 84
!                                 +--------------+

Segment  26
!
!                                     FB 3
!                                 +--------------+
!                                 !   TIMEB3     !
!                                 +--------------+

Segment  27
!           T 24
!F 6.7     +-----+
+---] [---+-!T!-!0!
!KT 300.0 --!TV BI!-
!          !    DE!-
!          !      !
!          !      !                                                          F 7.3
!        +-!R    Q!-+----------+----------+----------+----------+----------+--(   )-!
!          +-----+

Segment  28
!
!T 26      F 7.3     F 7.0                                                   F 7.7
+---]/[---+---] [---+---]/[---+----------+----------+----------+----------+--(   )-!

Segment  29
!           T 25
!F 7.7     +-----+
+---] [---+-!1_-_V!
!DW 90    --!TV BI!-
!          !    DE!-
!          !      !
!          !      !                                                          -on FW5
!        +-!R    Q!-+----------+----------+----------+----------+----------+--(   )-!
!          +-----+

Segment  30
!           T 26
!-on FW5   +-----+
+---]/[---+-!1_-_V!
!KT 100.1 --!TV BI!-
!          !    DE!-
!          !      !
!          !      !                                                          F 8.1
!        +-!R    Q!-+----------+----------+----------+----------+----------+--(   )-!
!          +-----+

Segment  31
!
!                                  FB 243
!                                 +--------------+
!                                 !   DIV:16     !
!                     DW 86     --!Z1        OV  !-- F 1.2
!                     DW 68     --!Z2        FEH !-- F 1.2
!                                 !          Z3=0!-- F 1.2
!                                 !          Z4=0!-- F 1.2
!                                 !          Z3  !-- DW 87
!                                 !          Z4  !-- DW 88
!                                 +--------------+
```

```
Segment  32
!
!                                     FB 241
!                                    +--------------+
!                                    !   COD:16     !
!                          DW 87   --!DUAL      SBCD!-- F 1.2
!                                    !          BCD2!-- DR 203
!                                    !          BCD1!-- DW 89
!                                    +--------------+


Segment  33
!
!                                     FB 4
!                                    +--------------+
!                                    !   TIMEB4     !
!                                    +--------------+

Segment  34
!            T 27
!T 24         +-----+
+---] [---+-!T!-!0!
!KT 300.0 --!TV BI!-
!           !    DE!-
!           !      !
!           !      !                                                            F 7.6
!         +-!R    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+

Segment  35
!
!T 29       T 27       F 7.0                                                    F 7.4
+---]/[---+---] [---+---]/[---+---------+---------+---------+---------+--(   )-!

Segment  36
!            T 28
!F 7.4        +-----+
+---] [---+-!1_-_V!
!DW 85    --!TV BI!-
!           !    DE!-
!           !      !
!           !      !                                                            -on FW4
!         +-!R    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+
Segment  37
!            T 29
!-on FW4      +-----+
+---]/[---+-!1_-_V!
!KT 100.1 --!TV BI!-
!           !    DE!-
!           !      !
!           !      !                                                            F 7.5
!         +-!R    Q!-+---------+---------+---------+---------+---------+--(   )-!
!           +-----+
!
!                                                                              :BE
```

FB 1

```
Segment  1
Name :TIMEBASE

     :L    DW  72
     :L    KH  0000
     :OW
     :T    DW  74
     :BE
```

FB 2

```
Segment  1
Name :TIMEB2

     :L    DW  78
     :L    KF  +0
     :OW
     :T    DW  79
     :BE
```

FB 3

```
Segment  1
Name :TIMEB3

     :L    DW  84
     :L    KH  0000
     :OW
     :T    DW  85
     :BE
```

FB 4

```
Segment  1
Name :TIMEB4

     :L    DW  89
     :L    KH  0000
     :OW
     :T    DW  90
     :BE
```

OB 1

```
Segment  1
!
!                                                                                   PB 1
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!


Segment  2
!
!                                                                                   PB 2
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!

Segment 3
!
!                                                                                   PB 3
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!
!
!
!
Segment 4

!
!                                                                                   PB 4
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!
!
!
Segment 5

!                                                                                   PB 5
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!
!
!
Segment 6

!                                                                                   PB 6
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!
!
!
Segment 7

!                                                                                   PB 7
+---------+---------+---------+---------+---------+---------+---------+--(JU )-!
!
!

 :BE
```

1. John R. Hackworth, Frederick D. Hackworth Jr., *Programmable Logic Controllers,* Pearson Education.

2. Bela G. Liptak, *INSTRUMENT ENGINEERS' HANDBOOK*, 3rd Edition.

3. Seimens' S5 100U Manual

4. CIMPLICITY Manual.

5. Glasstone Samuel, Sesonske Alexander "Nuclear Reactor Engineering Reactor Design Basics", CBS, Fourth Edition: Volume One, 2003.

6. Noboru Koshizuka, Toshihisia Muto, Ken Sakamura, Human-Machine Interface Specifications in the "Computing Everywhere" Age 1995 IEEE *Proceedings of TRON '95*

7. www.google.com

8. www.assemblyautomation.co.uk

9. www.dtic.mil