

# Computer controlled turbine run up and loading at Liddell Power Station

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THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF ELECTRICAL ENGINEERING

"COMPUTER CONTROLLED TURBINE RUN UP AND  
LOADING AT LIDDELL POWER STATION"

BY

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JOHN CRIPPS



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SUMMARY

The aim of this thesis is to describe the design considerations involved in implementing a computer controlled turbine run up and loading operation.

The project started in May, 1967 when the Electricity Commission of N.S.W. set up a working party (comprising representatives of the boiler contractor Combustion Engineering Inc., the turbine contractor, the English Electric Company of Australia Pty. Ltd. and the Commission) to discuss the desired run-up and loading procedures for the boiler/turbine units at Liddell power station. The procedures covered cold, warm and hot types of starts.

Discussions were then held with the computer Contractor to assess the core and disc storage required in the computer system to implement the function. In addition an estimate was made of the programming resources required for coding and checkout of the control programmes. This estimate fell well short of the actual programming man-days finally found to be required for this function.

Based on the minutes of the above discussions the Commission prepared a set of operational oriented flow charts (a total of 7 sheets) outlining the run-up and loading phases. The flow charts were sent out to the main plant contractors and the computer contractor for comments in October, 1968.

After reviewing all comments the next phase of the project was to translate the operational oriented flowcharts into a form suitable for direct coding by the computer contractor. This activity resulted in the number of flowcharts increasing ten fold. The Commission released sets of the final programme oriented flow charts to the computer contractor for coding in April, 1970.

The number 3 computer system (there are 4 computer systems, one for each boiler/turbine unit) was the first system which could be used for control programming work because the number 1 and 2 computer systems had already been air freighted to site and were in operation. However the number 3 system was not made available until December, 1970. Half way through the control programming work the No. 3 computer system was required at site for commissioning the main plant and so could no longer be used for this activity. The number 4 computer system was still undergoing hardware tests and could not be made available for control programming work for some months.

By October, 1971 the control flow charts were coded and checkout out statically. Work during the next three months concentrated on testing the control programmes under simulated plant operation.

The fully checked out control programmes were release to the Commission in January, 1973. The next phase of the project was to commission the control programmes. This was planned for February/March, 1973.

However, following serious unit failures at Munmorah and Liddell power stations the commissioning of the control function was postponed until September/October, 1973 (after the winter loading period).

In September/October, 1973 the commissioning activity was again postponed because of industrial strikes at the Commission's power stations. The revised commissioning date is for late 1974 or early 1975.

In the following sections it is proposed to outline the development and design of the control programmes, its various stages of testing and the final stage of commissioning.

Section 1, introduce the subject and outlines the project responsibilities.

Section 2, describes the power plant configuration.

Section 3, gives a description of the on-line real time computer system specified to implement routine data logging and the control function.

Section 4, outlines the extent of the control function in general terms.

Section 5, describes the more important design features of the control temperatures required to overcome some of the problems experienced overseas.

Section 6, describes the DDC package developed by the computer contractor and the interface between the DDC package and the control programme.

Section 7, gives a written explanation of a number of control flow charts. These were prepared to assist in staff training.

Section 8, describes the interface between the computer and the operator during the control function. The panel logic was designed by the Commission.

Section 9, outlines the software power plant simulator, developed by the Commission's consultants Ebasco Services Incorporated, New York and used to check out the control programmes.

Section 10, describes the control programme testing phase of the project.

Section 11, outlines the steps required to commission the control programmes.



Section 12, gives a list of comments on future digital control applications based on experience gained on this project.

The term "Commission" throughout this report refers to a small team of engineers of which I was a member.

8B.

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## 1. INTRODUCTION

### 1.1 JUSTIFICATION

The main reason for an automatic run-up system is to allow the turbine to be run-up, under all permissible start-up conditions, in the shortest possible time, compatible with thermal stress considerations. It is not only the reduction in the run-up period which is important, but also the long term objective of avoiding thermal overstress and the resulting reduction in the operational life of the turbine. There is no doubt that as the capacity of turbines continues to grow, thermal stress will have to be controlled to even closer margins calling for more refined techniques of on-line thermal stress assessment and more stringent control of turbine run-up and loading.

### 1.2 ALTERNATIVE MEANS OF IMPLEMENTING AN AUTOMATIC RUN-UP SYSTEM

Two alternative methods of approach are possible:

1. Analogue Type Turbine Run-Up Equipment - where the sequence of operation is pre-determined by wired programme; the equipment is capable of starting items of plant in a pre-determined order with appropriate checks included for various permissive conditions. The regulating duties are performed by analogue sub-loop control. Generally equipment of this type is inflexible - permits only a single path approach and due to limited intelligence the logic has to deliberately be on the safe side, viz., shut-down on any single abnormality whether really warranted or not, etc.

## 1.2

ALTERNATIVE MEANS OF IMPLEMENTING AN AUTOMATIC RUN-UP SYSTEM (CONT'D)

2. Stored Programme - viz., digital computers particularly if the latter are provided at power plant anyway for monitoring: data logging and thermal performance evaluation duties. In this situation the incremental cost of additional hardware required for the control of plant is reasonably low; on the other hand the programming costs may become substantial if the scope of automation is extended well beyond that available from the pre-wired equipment mentioned in (1) above. Another advantage of the stored programme approach is that computer programmes can be changed very easily and quickly whereas the fixed sequence system has to be re-wired, which is a lengthy and costly task.

## 1.3

CHARACTERISTICS FOR AN AUTOMATIC RUN-UP SYSTEM

In (Ref. 1 ), Mr. Hirnze from the CEGB stated that some of the more essential attributes of a computer control run-up system are as follows:

- i) It must be considered a useful tool by the operator
- ii) The operator must be able to intervene at any stage of control function.
- iii) It must be capable of recognising all expected plant operating and fault conditions and of taking the necessary corrective action to maintain the plant in a safe state.
- iv) The system must be sufficiently flexible to easily accommodate small known plant or instrument deficiencies.

1.3 CHARACTERISTICS FOR AN AUTOMATIC RUN-UP SYSTEM(CONT'D)

- v) The integrity of the system must be high and under a computer system fault condition should inhibit fail safe characteristics, which do not result in any hazard to the controlled plant.

1.4 PROJECT RESPONSIBILITIES

The responsibility for the development and future commissioning of the computer controlled turbine run-up and loading system is shared by the English Electric Company, Leeds and Northrup Australia Pty. Ltd., the Electricity Commission of N.S.W. and the Commission's Consultants Ebasco Services Incorporated, New York. The turbo-generator manufacturer, English Electric, was responsible for defining the basic run-up philosophy and providing all the necessary turbine data. It was the function of the Commission to forge all the various run-up requirements and the turbine data into a detailed engineering specification tailored to harmonise with the on-line computing system in whose framework the facility was to operate. This specification referred to the "Turbine Run-Up Flow Charts" was passed to Leeds and Northrup who executed the task of coding and that of integrating the resulting programme with the rest of the software system. The programmes were then checked against a software simulator designed by Ebasco Services Incorporated. The site testing of the programme and its final setting to work shall be carried out by a joint effort between the Commission, Ebasco Services Incorporated, and Leeds and Northrup Australia Pty. Ltd.

OVERSEAS TURBINE RUN-UP EXPERIENCES

Computer control of a turbine during run up and loaded has been attempted at a number of power stations overseas with a varying degree of success.

The following were some of the reasons quoted for the lack of success in this area:

1. initial control programmes from factory had not been adequately tested prior to commissioning.
2. the Commissioning Engineers could not "get the unit" enough times per year to correct the programme errors and power plant logic errors.
3. one or two errors per trial were found but the unit startup could not wait for the Engineer to fix the errors so the Engineer had to wait until the next unit outage to do so.
4. even when the Engineer made the original programme correct as a programme they found that it was necessary to operate differently which meant changing the programme and debugging it on the power plant again.
5. because of the above reasons the operating staff of most of the unsuccessful efforts have lost interest in pursuing the project.
6. one power plant where they successfully commissioned, their program has quit using it because the program used single inputs and operators became tired of "wedging" the contacts to make the indication right in order to get through the program.
7. a power plant simulator had not been provided to check out the control programmes.

## 2. THE PLANT ENVIRONMENT

To obtain a better understanding of the control requirements of the programme a brief description of the power plant configuration would seem useful at this stage.

### Boiler and Turbine

Each boiler is of the divided furnace, assisted circulation, drum type supplied by Combustion Engineering Superheater Overseas Ltd. rated to supply, 3,600,000 lbs/hr of steam at 2400 lbs/sq.in. and 1005°F at the superheater outlet and 3,160,000 lbs/hr at 578 lbs/sq.in. and 1005°F at the reheater outlet.

The English Electric turbines are of the tandem compound type with one high pressure cylinder, one double flow intermediate pressure cylinder and two double flow low pressure cylinders. The turbine drives a 500 MW hydrogen and water cooled generator which supplies power at 22 kV, 50 Hz.

### Fuel System

Each corner of the boiler is corner fired from eight pressurised Combustion Engineering Raymond bowl mills which are fitted with stock gravimetric belt type coal feeders. The cold primary air system is supplied by two constant speed primary air fans fitted with inlet vanes to control the output. Two tubular type primary air heaters supply hot air to the mills. Two elevations of retractable oil guns are provided for lighting up.

### Air System

The balanced draft air system comprises two constant speed axial flow forced draft fans and two constant speed

Air System (Cont'd)

centrifugal induced draft fans. The output of the forced draft fans is controlled by varying the blade pitch; the induced draft fans being controlled by inlet vanes. Two rotary type secondary air heaters are provided.

Steam Temperature

The steam temperature is controlled by tilting burners and spray desuperheaters. The position of the tilting burners is controlled to maintain the reheater outlet temperature, over superheating of the main steam being controlled by interstage spray desuperheating. Emergency spray desuperheating is provided for the reheated steam.

Feedwater

Two feed pumps are provided. One pump (50% duty) is driven by a constant speed electric motor, the output being controlled by a valve. The other pump (100% duty) is driven by an English Electric steam turbine and will be the normal source of boiler feedwater. The turbine uses steam at turbine stop valve conditions and normally exhausts to the cold reheat lines.

Throttle and Stop Valve Arrangement

The throttle and stop valve arrangement at Liddell power station consists of two identical parallel systems as shown on page 15.

(a) Turbine Throttle Valves

As recommended by the turbine contractor, the automatic turbine run-up and loading

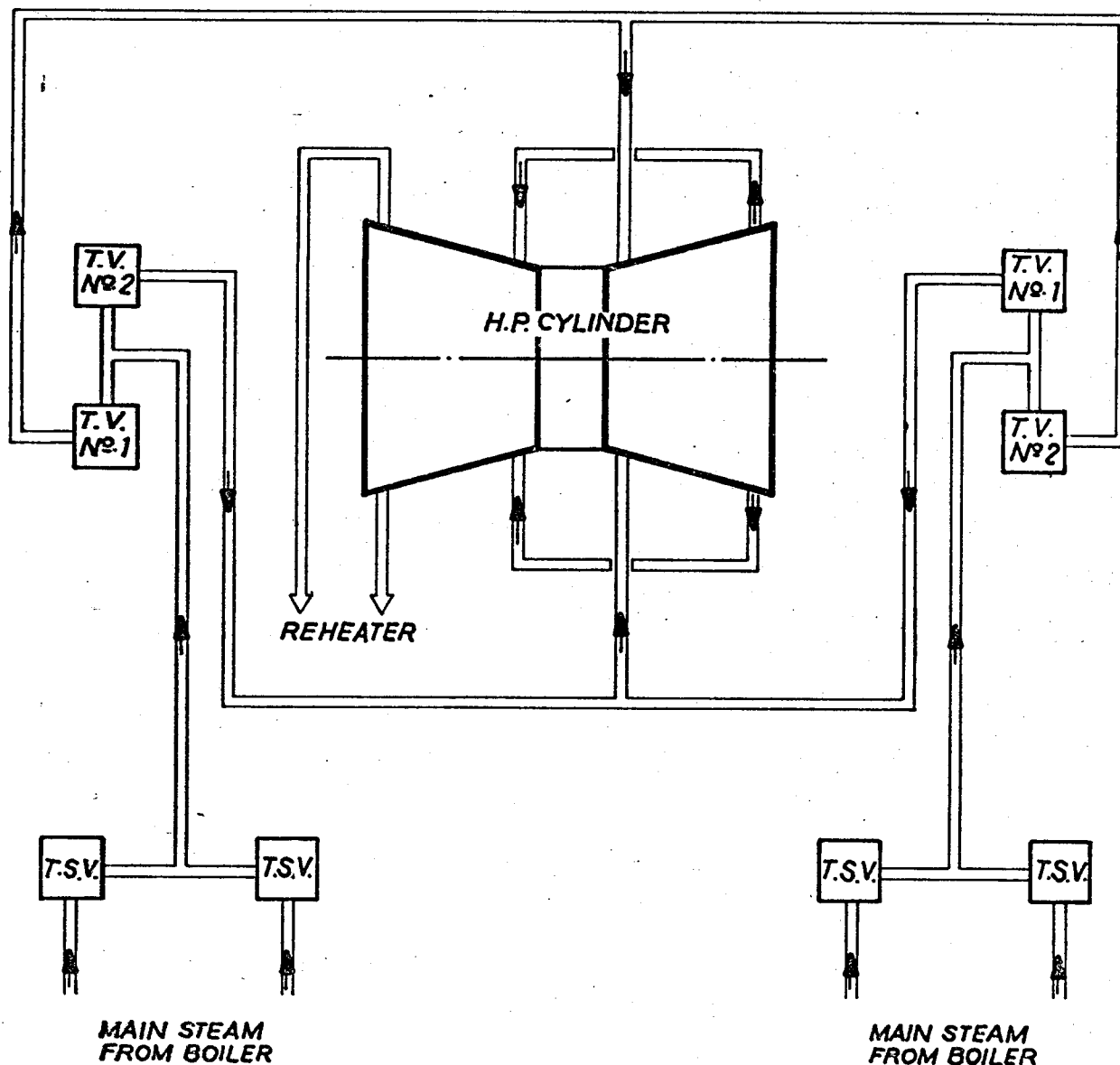


Throttle and Stop Valve Arrangement (Cont'd)

operation will be carried out by computer action on the turbine throttle valves.

The throttle valves are hydraulically operated by oil supplied at 200 lb/sq.in. from the power oil system.

The positioning signal to the four throttle valves is the governed oil pressure. Each of the No. 1 throttle valves has an internal pilot or bypass valve. On increasing governed oil



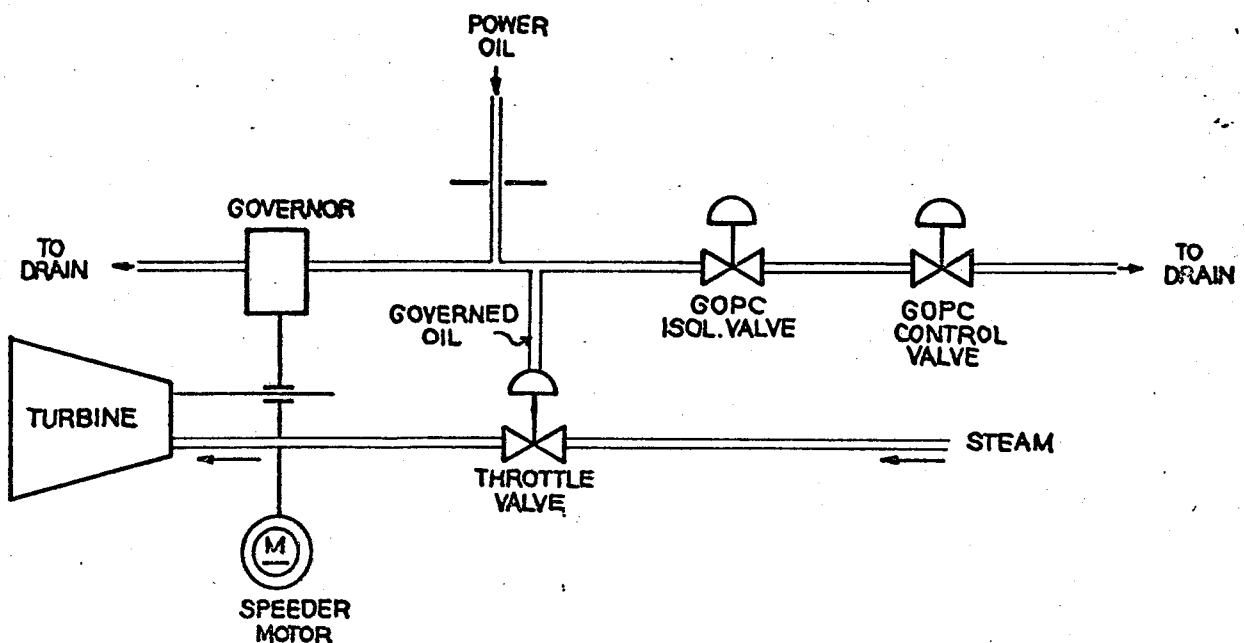
T.S.V. - Turbine Stop Valve.  
T.V. - Throttle Valve.

### Throttle and Stop Valve Arrangement (Cont'd)

pressure, the No. 1 throttle valves open fully and then the No. 2 throttle valves open (in practice the valves are set-up with an overlap).

Governed oil pressure is the pressure downstream of a restricting orifice and it can be controlled by varying the leakage rate (refer to figure below. There are two means of controlling the pressure (leakage) at Liddell:

- (i) Speeder gear - by speed action of governor flyballs or by computer action on the speeder gear motor.
- (ii) Governed Oil Pressure Controller (referred to as the G.O.P.C.) control valve - by computer action on the control valve actuator.



Throttle and Stop Valve Arrangement (CONT'D)

The functions of the G.O.P.C. control valve is to raise the pressure of the governed oil and in consequence open the throttle valves to raise the turbine speed (by closing the G.O.P.C. control valve) from 100 r.p.m. (barring speed) to 2940 r.p.m. At this speed the G.O.P.C. control valve ceases to function and control of speed is passed over to the speed governor.

Governed oil is shut off from the G.O.P.C. by a motorised isolating valve when the unit is synchronised.

To control the possible fluctuations in turbine output due to boiler pressure fluctuations the boiler/turbine unit will be loaded with the No. 1 throttle valves fully open and the No. 2 throttle valves at about 50% opening for control (refer to page 10 for details).

(b) Turbine Stop Valves

Prior to commencing the automatic run-up the turbine stop valves have to be open. Hardware was provided for opening the turbine stop valves at a fast or slow rate. The plan was for the control function to call for slow opening of the stop valves for thirty seconds before opening at a fast rate. This was to prevent inadvertent uncontrolled acceleration to take place if the throttle valves were not tightly closed.

Direct Digital Control of the G.O.P.C. Control Valve

The G.O.P.C. hardware provided by English Electric Company for computer controlled run-up consisted of an analogue control loop (refer to Appendix A), the set point of which can be incremented either manually or by the computer during the acceleration process.

Direct Digital Control of the G.O.P.C. Control Valve  
(Cont'd)

However, because it appeared doubtful whether the equipment could provide good speed control, both under low and full inlet steam conditions without the need for retuning the controller at every change in conditions the Commission decided that for controlled run-up the computer would act on the G.O.P.C. control valve actuator using direct digital control (DDC). With direct digital control (DDC) the computer can vary the controller coefficients to obtain tight control over the wide range of plant operating conditions.

However, the G.O.P.C. analogue speed control loop was retained for analog backup if the computer malfunctions during the automatic run-up operation.

Hardware Automatic Synchroniser

During the early design stage of the control function the Commission, in agreement with the turbine contractor, decided to use the Brush Automatic Synchronising equipment to synchronise the unit.

The Brush Synchronising equipment is a fully transistorised unit designed to carry out the following functions:

- a) It brings the incoming alternator into an acceptable operating condition, both in voltage and speed, for synchronising to be carried out.

Hardware Automatic Synchroniser (Cont'd)

- b) It initiates the closure of the generator breaker at an instant in time such that the breaker will close within given limits of phase coincidence of the running and incoming voltages.

The automatic synchroniser operates on the speeder gear by sending pulses of fixed length in the downward direction. The speed is lowered slowly under control of the governor mechanism. The generator breaker is closed as the speed passes through 3000 rpm.

Analogue Back-Up Speed Control Loop

The functional arrangement of the analogue speed control loop is shown in Appendix A. The analogue loop operates as follows:

The actual speed of the turbine measured by the tacho-generator is compared to a set point of desired speed and the error signal is fed to a 3-term controller which positions the drive unit. Drive unit positional feedback to the controller is modified by a factor of pressure before the throttle valve to allow for variations in turbine input conditions affecting the controller proportional and integral response.

A rate limiting control is exercised on the drive unit "close" signal which prevents further closing of the G.O.P.C. control valve whenever the acceleration of the turbine exceeds a preset rate.

Analogue Back-Up Speed Control Loop (Cont'd)

The system is arranged so that on selection of the computer for direct digital control (DDC) of the drive unit, the analogue controller is used in a servo follower circuit to maintain the analogue speed set point at the actual speed of the turbine so that return to analogue control is executed in a bumpless manner.

Unit Co-Ordinated Analogue Control System

For the automatic loading phase of the control function, it was decided that the computer would act upon the required output set point and pressure set point of the co-ordinated analogue control system. A functional arrangement of the analogue control system used for the computer controlled loading operation is shown in Appendix B. A description to the system is as follows:

The required output signal is introduced as a feed forward or anticipating action to provide parallel operation of all the manipulated variables during a change in output requirement. This anticipating action is from required output to the turbine governor, fuel, and air. The necessary calibrating adjustments and time functions are included for each manipulated variable in order to:

- 1) Provide maximum response to load changes,
- 2) Minimise the variations in pressure, temperature, and  $O_2$  during changes in output.

Unit Co-Ordinated Analogue Control System (CONT'D)

The remaining control actions are designed to accommodate the interrelationships of firing rate changes on pressure and megawatts in combination with the corresponding effects of turbine governor regulation on pressure and megawatts.

Limit and runback logic, as well as rate-of-change setters, are provided to keep the required output signal within the capabilities of the unit auxiliaries in service. For example, on loss of an auxiliary, such as one of the forced draft fans, the required output is operated to a corresponding safe limit, and the unit output is automatically reduced to match this requirement.

The main controls signals - namely required throttle valve position, required fuel and required air are derived as follows:

The required throttle valve position signal is determined from a combination of required output signals (as determined by the computer), and pressure correction signal. This signal is then compared with the actual valve position and the error signal sent via the governor controller to the turbine governor motor actuator.

The required fuel and air signal is established from a combination of the required output signal and oxygen correction signal.

Unit Co-Ordinated Analogue Control System (Cont'd)

The required fuel signal is then compared with the actual fuel signal obtained by summation of coal weigher signals from each pulverising mill group and the total fuel oil flow. The resulting fuel error signal is sent via the fuel controller to each milling group coal feeder speed adjusting mechanism (a total of 8 milling groups).

Provision is also made for the fuel error signal to be sent to each milling group primary air flow control loop and to the secondary fuel-air damper control loop.

The required air signal is compared with the actual air signal to determine the air flow error. However, the required air flow is not allowed to drop below a certain value to ensure safe operation of the boiler furnace; that value is to be determined by the minimum air flow set point which will be set at approximately 30% of C.M.R. air flow. The air flow error signal is sent via the air flow controller to the forced draft fan blade pitch adjusting mechanism (two forced draft fans of axial flow type).

An automatic balancing network and a manual bias facility has been provided to permit equalising of duty on each fan.

The oxygen in flue gas error signal is determined by the comparison of actual oxygen measurement with oxygen set point. The latter is required to be automatically variable in



Unit Co-Ordinated Analogue Control System (Cont'd)

function of the actual boiler steam flow to permit operation at constant oxygen content in the higher load range and linearly increasing oxygen content below a certain load. Means of adjustment are provided for:

- a) the minimum oxygen value,
- b) the slope of oxygen variation vx. steam flow,
- c) the steam flow below which the oxygen content begins to rise with diminishing steam flow.

RUN UP PHILOSOPHY

The control programmes are designed to handle four different start up conditions as follows:

1. Cold Start
2. Warm Start
3. Hot Start
4. Hot Recovery

Refer to page 26 for a summary of the plant conditions during the above types of start up. The following is a description of the cold and hot run-up cases.

Cold Run Up

It is assumed in this case the turbine has not operated for several days and the casing temperatures have cooled to near ambient temperature.

Cold Run Up (Cont'd)

Once the unit is ready for firing, the warm up oil guns are placed in service and heating starts at a rate of about 300°F saturation temperature increase per hour.

The turbine stop valves are then shut and steam pressure is raised to 400 psig. At this the pressure vacuum raising is initiated. After full vacuum has been raised the turbine is rolled from barring speed to 2000 rpm in approximately 10 minutes.

The speed is then held at 2000 rpm while heat soaking of the I.P. cylinder takes place. The holding time will depend on I.P. steam to metal temperature differential. If the temperature differential is less than or equal to 100°F, then the holding time will be zero. If the temperature differential is 400°F, then the holding time will be 30 minutes and if the temperature differential is 600°, then the holding time is 90 minutes.

After this period, the turbine is brought up to 3000 rpm in a few minutes and synchronised. A block load of 25 MW is then applied.

In order to cope with the steam demand of this period, which increases from 220,000 lbs/hr when running at 3000 rpm to over 370,000 lbs/hr after the block load is applied, a mill is pre-warmed and placed in service five to ten minutes prior to synchronising.

The load is then applied to the turbine by increasing the boiler pressure and leaving the turbine throttle valves substantially open (about 50%). The rate of loading is

Cold Run Up (Cont'd)

approximately 1 MW per minute.

When at 300 MW, the boiler pressure will be about 1700 psig and the steam temperatures will reach the rated condition of 1005°F.

Then the load may be increased to full load in 20 minutes in conjunction with increasing the boiler pressure. The total starting time from initial rolling of the turbine to full load on the unit is estimated at approximately seven hours.

Hot Run Up

A hot run up occurs when the turbine is accelerated after approximately a twelve hour shut down.

The anticipated steam conditions at the beginning of the run-up are:

Steam Pressure 500 psig

Steam Temperature 550°F

The turbine is accelerated to 3000 rpm in approximately 10 minutes. During this time at least two mills have to be started and prewarmed in readiness for the fast loading period. After the turbine has been synchronised, a block load of 25 MW is applied. The loading of the turbine will then be carried out at a rate of 10 MW/minute resulting in the full load being obtained in approximately 45 to 50 minutes.

SUMMARY OF START UP CONDITIONS AND PLANT LIMITS

	HOT RECOVERY	HOT	WARM	COLD
<u>Definition of Type of Start:</u>				
I.P. Inner Casing Metal Temp. °F	800	700	450	450
H.P. Inner Casing Metal Temp. °F	800	720	500	500
H.P. Pedestal Expansion	K1	K2	K3	K3
Approx. Corresponding Duration of Outage Time Prior to Start, Hours	1	12	68	68
<u>Anticipated Steam Conditions</u>				
<u>At Beginning of Run-Up:</u>				
Steam Pressure, psig	1800	500	500	420
Steam Temperature, °F	900	550	550	550
<u>At Synchronising:</u>				
Steam Pressure, psig	2000	800	700	650
Steam Temperature, °F	950	750	620	600
Reheat Temperature, °F	900	700	620	600
<u>Starting Parameters:</u>				
Acceleration Rate, rpm/min.	296	296	190	190
Hold Time at 2,000 rpm	none	none	variable up to 90 min.	
Block Load, MW	75	25	25	25
Loading Rate, MW/min.	10.0	10.0	2.5	1.0
Pressure Set Point Increase Rate, psi/min.	33.0	33.0	8.7	5.8

NOTE: The value of K1, K2, and K3 to be determined from operating experience.

### 3. THE ON-LINE REAL TIME COMPUTER SYSTEM

#### 3.1 GENERAL DESCRIPTION

The on-line computer system at Liddell Power Station is based on the Leeds and Northrup LN5200 Digital Computer System. One system is associated with each of the boiler/turbo-generator unit. A hardware block diagram of the system is shown in Appendix C

The LN5200 Digital Computer System uses the Xerox Data System Sigma II as the central Processor (refer to Appendix D for C.P.U. characteristics). The core memory cycle time of the machine is approximately 900 nanoseconds. Each word consists of 16 bits plus a parity bit. The computer has a powerful priority interrupt system and two effective means of performing input/output functions. Power fail-safe, selective memory protection and rapid context switching are among the many features of the computer. A total of 44,000 words of core memory is provided.

Seven general registers are used for programme control information (a programme address register, a link address register, an accumulator, extended accumulator, temporary storage register, index register and index register 2).

Each Liddell system includes twenty-one distinct levels of interrupt, each with its own identification and priority. Each level can be individually disarmed, to discontinue response, and/or disable, to defer response, which permits dynamic reassignment of priorities even during actual execution of a real-time programme. The LN5200's rapid context-switching permits interrupt processing to begin promptly; without time consuming overhead.

Analogue inputs are brought in under interrupt control, with the interrupt signifying that the selection and analogue-to-

### 3.1 GENERAL DESCRIPTION (CONT'D)

digital conversion process is complete, and the input data is ready for the computer to read.

Integrated circuits are employed where appropriate throughout the system. Those used in the I/O subsystem which must interface with the process are of a type having a high threshold voltage producing high noise immunity. This, in conjunction with careful filtering, results in system inputs having extremely high integrity.

The I/O equipment is so designed that a component failure will normally affect the operation of only a small portion of the system, allowing the rest of the system to function normally. Modular construction allows quick location and replacement of a failed circuit. Redundancy techniques are used to back up critical multiplexed portions of the I/O equipment such as the analogue input amplifiers, the analogue-to-digital converter and the power supplies.

The functions performed by the on-line computer system at Liddell Power Station can be divided into four main categories:

- i) Plant Monitoring - involving continuous scanning of measurements from plant, comparing these with alarm settings and raising alarms as required.
- ii) Data Logging and Display - involving the display or printing of data when requested by the operator, automatic gathering of selected data during plant disturbance, automatic logging of selected information at regular intervals and the long-term storage and retrieval of data.
- iii) Calculations - involving the automatic calculation of variables from scanned input data and/or variables already calculated.

### 3.1 GENERAL DESCRIPTION (CONT'D)

- iv) Control Functions - implement an automatic run-up and loading control function.

Appendix E summarises the overall system functions.

### 3.2 SIGMA II INPUT/OUTPUT COMMUNICATION SYSTEMS (REF. 2 )

The Sigma II has two distinct input-output communication systems:

#### i) Direct-to-CPU Input/Output System (DIO)

The direct-to-CPU input/output system (DIO) is the means for communication with the process input/output subsystem, and uses only a single instruction to transfer a full 16 bit data word to and from the A-register. To accomplish this the computer executes a read direct instruction to interrogate the status of 16 data lines, or a write direct instruction to affect the status of the 16 data lines. The origin or destination of the data on these lines can be controlled by 16 address lines on which the appropriate address is placed by the computer during execution of the instruction. Since it is necessary to execute read direct or write direct instructions for every set of 16 bits transferred, the data transmission is under direct control of the CPU; that is, the computer cannot be performing some other task, but must be intimately involved in the transfer. For instance, each character printed on an I/O subsystem typewriter requires one write direct instruction.

### 3.2 C.P.U. INPUT/OUTPUT SYSTEM (CONT'D)

#### ii) Input/Output Processor (IOP) System

The IOP, or byte-oriented system, has its own high speed registers and operates independently without requiring attention from the programme once it has been started. Data is transferred one byte at a time (8 bits plus a parity bit). For high speed peripherals, bytes are assembled into words in the I/O section, and only one memory reference is made for two bytes. All IOP channels may operate concurrently up to a combined transfer rate of 400,000 bytes per second.

The Input/Output Processor operates as follows:

The CPU informs the IOP of the starting address of a continuous block of core memory into which data are to be transferred from a selected peripheral device or from which data are to be transferred to a selected peripheral device. When the CPU transmits the byte count (length of the block of memory in 8-bit increments) and the device address, the transfer of data becomes automatic and the computer can go on to some other programme and perform some entirely unrelated function. The transfer of data bytes through the IOP interface will be automatic in the sense that it will not affect currently running programmes excepting by slowing them down. That is, time will be "stolen" from the computer in order to put the data into or out of core memory. The effect is that the computer average speed appears to be less while this data transfer is in progress.



### 3.2 C.P.U. INPUT/OUTPUT SYSTEM (CONT'D)

#### 11) Input/Output Processor (IOP) system (Cont'd)

For the four IOP channels in the Liddell system, eight I/O registers are provided. Each channel uses two of these registers to store control information to allow the simultaneous operation of the four channels.

Equipment such as the disc memory and magnetic tape unit use these channels so that time sharing of programme execution and important I/O can be done.

### 3.3 PROCESS INPUT/OUTPUT SUBSYSTEM (Refer to Appendix C )

The process Input/Output Subsystem serves as an interface between the computer and the process I/O. The term process I/O is used to describe the analogue and digital variables read by the computer or outputted by the computer. Analogue inputs include pressures, flows, temperatures, levels, analysis measurements, and valve positions. Digital inputs come from a wide variety of on-off or pulse type devices and include limit switches, push buttons, watt-hour meters, etc. Digital outputs are used to operate annunciators, to operate relays and printers, and through the DDC interface circuitry, to operate process control end-elements.

The Process I/O subsystem shown in Appendix C serves three functions. It is an interface between the signal levels used in the subsystem logic (0 to +12 volts for high noise immunity) and those used in the computer. It performs a timing function by returning an acknowledged signal to the computer in response to the function strobe signal accompanying each write direct or read direct operation, but delayed a sufficient amount of time to allow the subsystem to respond.

### 3.3 PROCESS INPUT/OUTPUT SUBSYSTEM (CONT'D)

It performs the function of translating the write direct or read direct instruction and address into a signal to the proper digital or analogue input or output hardware.

### 3.4 PROCESS INPUTS AND OUTPUTS

#### 3.4.1 Analogue Inputs

All analogue inputs are connected to the process I/O subsystem by an analogue multiplexer, data amplifier and analogue to digital converter system. Figure 1 on page 35 gives the simplified block diagram of the LN5200 analogue input subsystem. The overall accuracy of the analogue input system taken from the analogue input terminal strips, including signal conditioning, is better than 0.1% of full scale for 99.6% of the readings (three sigma deviation).

Analogue input signals are divided into a low level and a high level group. The low level group includes such signals as thermocouples, resistance thermometers, etc. and are brought into the system at a maximum signal level of 50 millivolts. The high level group includes most flows, pressures, levels, etc., and are brought into the system at a maximum signal level of 1 volt. The field signals are scaled to the appropriate level by individual signal conditioning.

When the computer addresses a point for scanning, the associated point and bank (up to 48 points/bank) relays are pulled in and the transistor switch operates to connect the output to either the high gain or low gain input amplifier to the analogue-to-digital converter input. After sufficient time has been allowed for the signal to settle, the analogue-to-digital converter makes a conversion, presenting its digital output (consisting of a sign bit and 14 data bits) to the computer.

### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

#### 3.4.1 Analogue Inputs (Cont'd)

Analogue inputs were separated into high and low level groups to optimise the multiplexer scanning speed. For the same 3 sigma accuracy of 0.1% the high level points can be brought in at a rate of 900 points per second while the low level rate is limited to 120 points per second.

For thermocouple inputs an open circuit detection scheme is provided. The system uses a method of pulsing the thermocouple circuit while the analogue-to-digital converter is measuring its value as held on the "flying" capacitor. If the circuit cannot pass a certain current, it is declared to be an open circuit.

High reliability of the analogue input system is achieved by the inclusion of an on-line spare analogue-to-digital converter, input amplifiers and the power supplies.

Fixed check signals of 0, 1/2 scale, and  $\pm$  full scale are permanently wired into the analogue system and a programme makes periodic checks of these values, adjusting gain to correct for temperature co-efficients and drift. Whenever any of these points measure outside allowable limits, the primary amplifiers and analogue-to-digital converter are switched out and the redundant amplifiers and analogue-to-digital converter are switched into the system.

In order to ensure the maximum accuracy obtainable with the scanned analogue inputs, zero offset and gain factors are applied to every analogue input on every scan to correct the readings for the system errors.

### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

#### 3.4.1 Analogue Inputs (Cont'd)

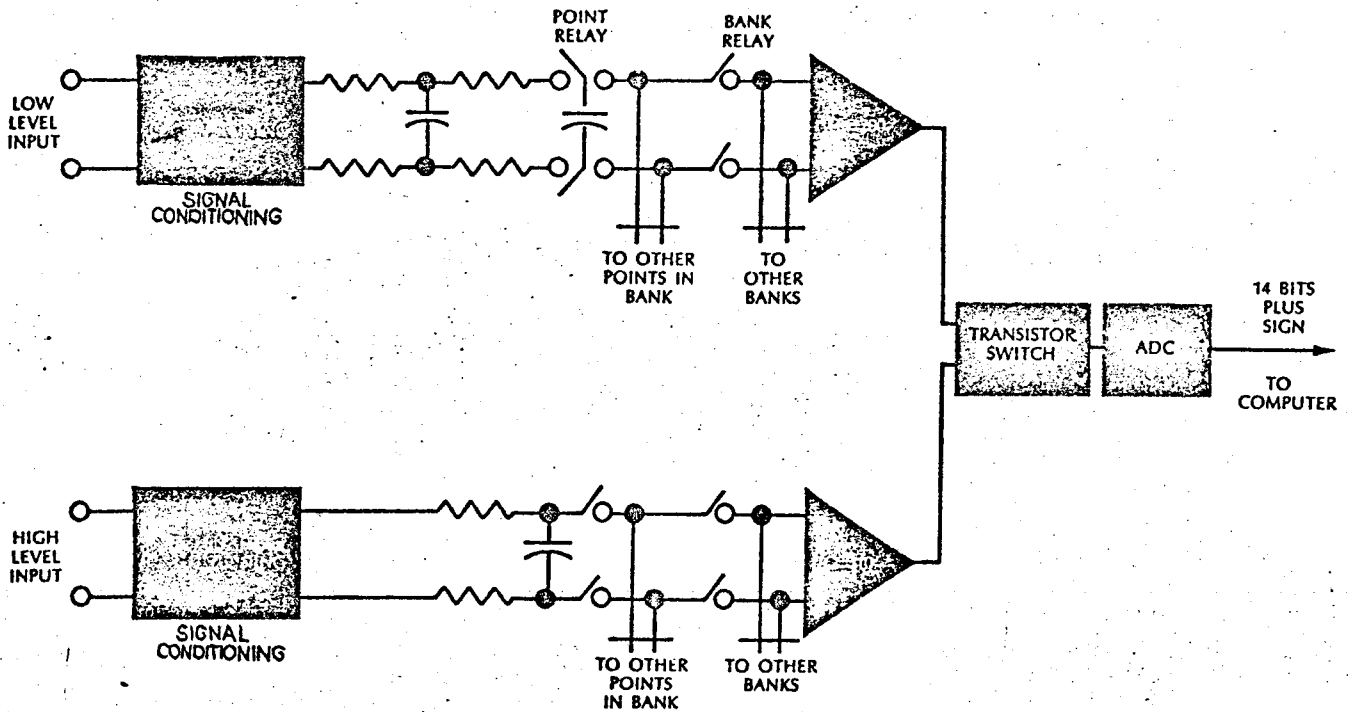
The low level multiplexer (Ref. 3) employs mercury-wetted relays for input selection and has a scanning rate of 120 point per second. The multiplexer accepts a 0 to 50 millivolt d.c. input signal and provides differential mode filtering with a two stage R-C network.. Multiplexing is accomplished by switching the last stage capacitor, which is charged up to the input voltage, to the input amplifier (refer to table 4 in Appendix F for specification of scaling amplifier) using a double-pole double-throw mercury-wetted relays as shown in Fig. 1 on page 35. High common mode noise rejection is achieved through the technique of "flying capacitors and differential amplification. The performance specification of the low level analogue inputs is shown in Table 1 in Appendix F .

The high level multiplexer (Ref. 3 ) employs dry reed relays for input selection and has a scanning rate of 900 point per second. The multiplexer accepts a 0 to 1 volt input signal and provides differential mode filtering with a signal stage R-C network. Multiplexing is accomplished by switching the input network with a double-ple signle-throw reed relay, to the input amplifier as shown in Figure below. The performance specification of the high level analogue input is shown in Table 1 in Appendix F .

A separate input amplifier is provided for the high-level and low level channels. The performance specification of the amplifier is shown in table 4 in Appendix F.

### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

#### 3.4.1 Analogue Inputs (Cont'd)



**FIG. 1** ANALOG INPUT SUB-SYSTEM

The analogue input timing allows sufficient time for the point relay to operate, the data amplifier to respond to the signal, and the analogue-to-digital conversion to be completed. At the termination of the timing cycle a priority interrupt is generated, signalling the computer that the data from the previously selected input is ready to read. The computer will respond with the read direct operation, outputting the address of the next input to be selected or terminating the scan, as determined by the programme.

Detail specification of the analogue-to-digital converter is given in table 5 of Appendix F.

### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

#### 3.4.2 Digital Inputs (Refer table 2 in Appendix F)

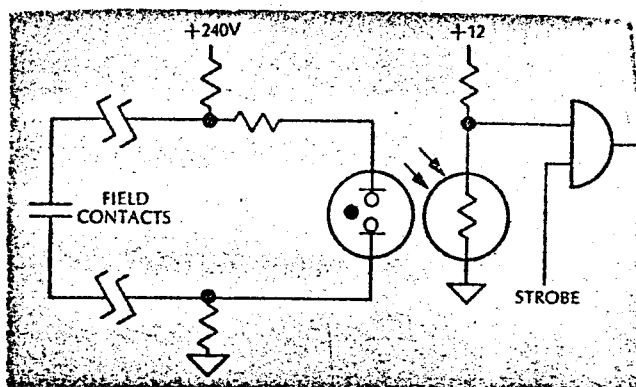
The solid state digital status input scanner accommodates 900 digital inputs per unit which are scanned every one second. The inputs are provided as Optically Filtered Digital Inputs (Ref.3 ) as shown in Fig.2 on page 37. This circuit offers high noise-rejection and a large voltage for film breakdown of the field contacts. The high noise rejection comes from two factors: the connection of the contact to turn off the lamp upon closure, and the long time delay between turning off the lamp and the effect of this upon the gate input. Approximately 100 V must appear across the input to the circuit for the neon lamp to fire. If any noise is to cause the lamp to fire, it is necessary that 100 V be generated differentially across the input when the contact is closed. When the lamp is lit (open contact) any noise must cause the lamp to extinguish for approximately 200 ms before the noise would have any effect.

Digital input bits are grouped in 16-bit sets, corresponding to the 16 data bits transmitted to or from the DIO. Each group of 16 bits, referred to as a data word, is selected by eight bits of the 16 DIO address lines. The digital input and digital output words are each arranged in 16 by 16 matrices, yielding a maximum of 256 input words.

A digital input word is selected by executing a read direct instruction, with the eight most significant bits of the address indicating a digital input operation, and the eight least significant bits indicating the desired input word. The function strobe signal causes the 16 data bits to be transferred from the selected input word to the DIO.

### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

#### 3.4.2 Digital Inputs (Cont'd)



**FIG. 2 OPTICALLY FILTERED DIGITAL INPUT CIRCUIT**

Digital inputs which are detected only when a change of state occurs are referred to as digital event inputs. Whenever a digital event input changes state a priority interrupt is sent to the computer. This is used to cause the computer to execute a programme which scans all the digital event inputs to see which one(s) have changed state. The sequence resolution achieved in the Liddell system is 2 ms while the time resolution is 4.2 ms.

#### 3.4.3 Pulse Inputs

Many process signals are presented to the system as pulse signals. Flow meters, conveyor belt speed indicators, tachometers, wattmeters are typical process devices which transmit measurements in pulse rate form. The system handles such inputs by accumulating the pulses in a 4 bit hardware counter register which the computer reads once each second. The pulse count scanned each second is accumulated in memory. Every two minutes the accumulation is converted to engineering units. The maximum pulse rate without losing information is 16 pulses per second.

### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

#### 3.4.4 Analogue Outputs

Sixteen digital-to-analogue Converters are provided in the system for trend recorders outputs. Sixteen data bits are sent to each digital-to-analog converter. The first bit is interpreted as the sign of the required output and the next 10 bits as the value (the 2's complement of the value for negative outputs). The last five bits are not used. The digital-to-analogue converter consists of storage for the 11 bits, along with reference voltages, precision resistors and transistor switch for converting to an analogue value, as well as amplifiers for providing the current output of 1-5 MA. The digital-to-analogue converter provides a resolution and accuracy of 0.1% and the conversion time is 200 microseconds.

#### 3.4.5 Digital Outputs

This equipment provides the means by which plant control is effected. There are a total of 208 digital output circuits per unit at Liddell. Each circuit comprises of a magnetically latched output relay which may be set and reset under programme control. In series with each digital output contact used in control is a further isolation relay contact. This permits all the output circuits to be isolated from the plant in event of a computer problem. Refer to section 6 for a more detailed description of digital output.

### 3.5 POWER FAILSAFE

The power failsafe feature provides power-on and power-off interrupt levels that are used to enter routines that save and restore valuable information and control the shutdown and startup of the system in an orderly manner in the event of a power failure.



### 3.4 PROCESS INPUTS AND OUTPUTS (CONT'D)

### 3.6 PRIMARY POWER SUPPLIES

The primary power supply to the computer system is from a three-phase solid state inverter. During normal operation the line power will be rectified and regulated and used to drive the inverter as well as keep a battery system charged. In case of power line failure, the batteries take over the power to the inverter for a period of time (approximately  $\frac{1}{2}$  hour). The power supply system also includes standby inverter. The changeover from normal to standby supply to the computer system is a manual operation.

### 3.7 PERIPHERAL EQUIPMENT

The man computer interface is achieved with the following peripheral equipment:

- a) Two computer communications panels, which contain various push buttons and selector switches whereby the operator can demand and specify the information that he requires from the computer or carry out limited changes to the software. These include alarm limits; scan frequency; etc. (refer to page 43A for layout drawing)
- b) Three wide carriage typewriters for system logging functions.
- c) Two high speed strip printers for alarm messages, status messages, and other important data for the operator.
- d) One X-Y plotter (one plotter for two units) used by the plant engineering staff to correlate plant data and study historical records.

- e) Fourteen trend pens in 5 recorders for monitoring plant data as required by the operator.
- f) Two digital display units for displaying important plant data.
- g) A trouble location annunciator system. 64 windows identifying an area of plant and operating like conventional annunciators, except that many points may activate the one window.
- h) High speed paper tape punch and reader and a teletype for on-line and off-line programming use.
- i) Magnetic tape unit for long term storage and retrieval of plant operating and alarm information.
- j) Magnetic disc memory for data and system programme storage.
- k) Turbine run-up and loading control panel.

Appendix G summarises the performance characteristics of the peripheral equipment.

### 3.8. RELIABILITY OF THE COMPUTER SYSTEM

The Liddell computer specification called an availability test to be carried out on each computed system over six consecutive months to demonstrate that the system meets the guaranteed figure of 99% (i.e. down time of less than 44 hours over the six consecutive months).

The system was considered available as long as it could continue to operate and perform all normal functions (note: the on-line spare devices could be used and the system considered available).

Units 1-4 computer system have all achieved this availability figure.

The curve in Appendix T shows the system availability curve and types of failures which have occurred on the Unit No. 2, computer system.

### 3.9. LN5200 SYSTEM STANDARD SOFTWARE

The following software programmes were supplied with each LN5200 computer system at Liddell Power Station:

#### REAL TIME EXECUTIVE:

The real time executive (called Central Resources Control) controls and allocates (according to priority) the system resources which are:

- (a) core memory
- (b) peripheral I-O
- (c) core and disc transfers
- (d) CPU time

#### INPUT/OUTPUT SUBSYSTEM:

Called the Printed Message Subsystem (PMS). The function of the PMS is to handle character message output to all printing and typing peripheral devices.

#### UTILITY PROGRAMMES:

The System Debug Utility software package (called SDUP) provides a means of debugging software system programmes during system test.

MONITOR  
PROGRAMME:

A background executive facility called LN Monitor controls accesses to the on-line background processors and also monitors for programming errors to insure the integrity of the foreground functions.

ASSEMBLER:

Called "XSYMBOL".

COMPILER:

Called SPL IV (refer to section 10 for details).

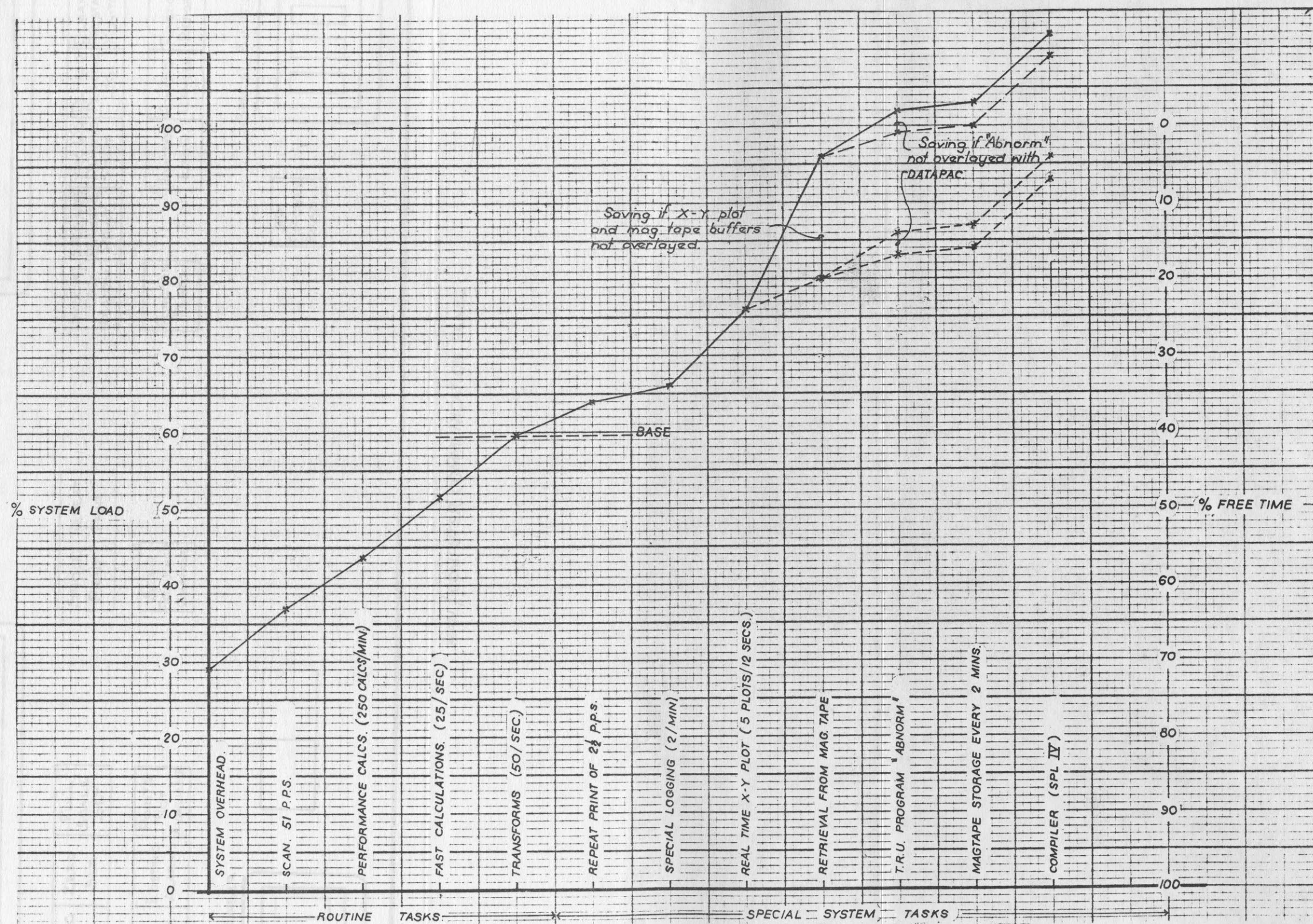
APPLICATION  
SOFTWARE:

Called the Data Acquisition, Processing, Alarm and Control System software (i.e., DATAPAC).

3.10. SYSTEM LOADING DATA

The Liddell Computer System loading curve is shown on page 43. From the curve it can be seen that the routine tasks take up approximately 60% of computer time. The remaining 40% of computer time can then be used for special system tasks.





POINT NUMBER.

--	--	--	--	--	--	--	--	--	--

ANALOG TREND.	ZERO SET.	FULL SCALE SET.
------------------	--------------	-----------------------

SINGLE PRINT.	REPEAT PRINT.
------------------	------------------

SHIFT REVIEW.	EXISTING ALARM.	POINTS NOT AVAILABLE
------------------	--------------------	----------------------------

SCAN FREQUENCY CHANGE
-----------------------------

PEN NUMBER.

--	--

--	--

DATA.

--	--	--	--	--	--	--	--

SPECIAL LOG ASSIGN.	SPEC. LOG PERIODIC PRINT.	SPEC LOG DEMAND PRINT.	DEMAND PERIODIC LOG.	DEMAND PRESTART MONITOR.
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FUNCTION RESET.
--------------------

FUNCTION EXEC.	FUNCTION CANCEL.	FUNCTION REPORT.
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SPECIAL FUNCTION.

SP FUNCTION ENABLE.
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MAN./COMPUTER COMMUNICATION PANEL

43A.

#### 4. OUTLINE OF CONTROL FUNCTION

##### 4.1 EXTENT OF CONTROL FUNCTIONS

The control programme has been designed to implement automatic turbine run-up and loading which consists of the following steps, each of which is described in detail later:

- i) Pre-roll checks;
- ii) Run-up of the machine from barring speed to synchronous speed;
- iii) Synchronising and block loading;
- iv) Loading to a pre-set target load.

Prior to automatic run-up the operator is responsible for establishing the necessary plant conditions.

The maintenance of correct steam conditions at the turbine during the start-up progress, involving the control of boiler firing rate, air flow, and steam throughput was not included in the control function.

##### 4.2 METHOD OF CONTROL

The control function was designed to be initiated by the operator from the turbine run-up control panel insert (refer to Section 8 page 110A). This insert, which is located on the unit control board contains a number of indicating lights to allow the operator to follow the progress of the run-up and loading phase as well as a number of operator control push buttons and selector switches.

##### 4.3 OPERATOR PARTICIPATION

During the run-up and loading phase, a certain degree of operator participation is necessary to:

#### 4.3 OPERATOR PARTICIPATION (CONT'D)

- a) Select G.O.P.C. control valve to computer control;
- b) Select G.O.P.C. isolate valve to computer control;
- c) Select turbine speeder gear motor to computer control;
- d) Initiate the run-up sequence;
- e) Apply excitation to the generator;
- f) Select the synchronising bus;
- g) Transfer control to the automatic synchronising equipment;
- h) Select the analogue control equipment to computer control;
- i) Control the firing rate of the boiler (including the pre-heating and placing of mills in service, etc.);
- j) Start the loading sequence.

#### 4.4 PRE-START MONITORING LOGS

The pre-start monitoring function allows the operator to demand print the status of any one of the plant status logs. This function is to be used by the operating staff prior to initiating the computer controlled run-up, with the objective of saving the operator time in detailed checking of the plant. Continuous monitoring was not required.

The report obtained will name the abnormalities in the log, enabling the operator to quickly determine what items of plant require attention before the run-up is started.

The function compares the actual status of inputs to the log with the normal status stored for each input. The normal status can be as follows:



#### 4.4 PRE-START MONITORING LOGS (CONT'D)

- a) Digital Input - True or False (open or close)
- b) Analogue or Calculated Value - Check can be made for three states, not in alarm, below a given value and above a given value.

Two "normal" status maps are kept for the variables in each log. Determination of which status map should be used is dependent on a unique formula for each log. The formula works on three status type inputs.

When demanded a group of inputs is checked against its appropriate normal map. For all abnormal inputs, the English description and status will be printed.

The software design enables the pre-start monitoring logs to be defined or changed on-line.

#### 4.5 DESCRIPTION OF CONTROL FUNCTIONS

##### 4.5.1 Pre-Roll Checks

During the pre-roll phase of operation (Boiler firing has already begun) the computer system is called upon to provide a number of checks on turbine auxiliary (and other) systems, commissioned by the operator. The main purpose of this function is to ensure that essential pre-start requirements still exist immediately prior to initiating any control action. It is designed to notify the operator of any significant changes which may have occurred in the interim period between the clearing of the main comprehensive pre-start monitor checks, and the actual "ready to run-up" time. The systems included in the pre-roll check facility are:

4.5 DESCRIPTION OF CONTROL FUNCTION (CONT'D)4.5.1 Pre-Roll Checks (Cont'd)

- a) Circulating water system (main condenser)
- b) Distilled water system (stator cooling, hydrogen coolers, etc.);
- c) Stator water system;
- d) Lubricating oil system;
- e) Turbine barring gear system;
- f) Power oil system;
- g) Seal oil system;
- h) Vacuum raising system;
- i) Condensate system;
- j) L.P. exhaust sprays.

4.5.2 Running-up of the Turbine to Speed

After the pre-roll checks have been all satisfied the computer will initiate the turbine run-up control function. The rotor acceleration will be controlled by computer action on the GOPC control valve until the speed comes into the control range of the turbine speed governor.

The computer system will execute the following steps in implementing this phase of the control function:

1. Preparations for the run-up, including:
  - a) running the speeder gear motor to minimum speed position (to drain governor oil through the primary relay);
  - b) Open the G.O.P.C. isolating valve;
  - c) Open the G.O.P.C. modulating control valve

4.5 DESCRIPTION OF CONTROL FUNCTION (CONT'D)4.5.2 Running-Up of the Turbine to Speed (Cont'd)

- d) run the speeder gear motor up from the minimum speed position to 2940 r.p.m. position determined by a limit switch.
2. Determine on the basis of turbine metal temperatures (i.e. H.P. and I.P. casing inner metal temperatures) and H.P. pedestal expansion whether to implement a hot, warm, or cold start. From the type of start the computer selects the acceleration and loading parameters.
3. Control the run-up of turbine by using direct digital control (DDC) technique on the G.O.P.C. control valve actuator until the speed comes into the control range of the main turbine governor. At this point the G.O.P.C. isolating valve is closed. Further acceleration of the turbine is carried out by the computer acting on the speeder gear motor.

The operator has the responsibility to ensure that mills are warmed up and one or more of them are placed in service at the appropriate time.
4. At a speed slightly in excess of synchronous speed the computer system signals to the operator that the turbine can be prepared to synchronising.

4.5.3 Synchronising and Block Loading

The computer system then checks if the pre-requisites for synchronising (field switch closed and generator excited to minimum,

#### 4.5 DESCRIPTION OF CONTROL FUNCTION (CONT'D)

##### 4.5.3 Synchronising and Block Loading (Cont'd)

generator bus voltage satisfactory, automatic voltage regulator (AVR) on auto, bus to which generator will be synchronised selected) are satisfied before requesting the operator to initiate the automatic synchroniser.

The automatic synchroniser matches the incoming and running voltages across the main circuit breaker (by the A.V.R. voltage setting rheostat) and pulses the speeder gear motor down at a fixed rate. This allows the machine to coast down to a point of minimum acceptable speed and phase error before synchronising.

After the generator has been synchronised, the computer will automatically increase the magnitude of the block load by acting on the speeder gear motor) above the value inherently placed on the generator during the synchronising process. Values of block load will be based on the same measurements as that used to determine the run-up rates.

##### 4.5.4 Loading to a Pre-Set Target Load

At this point, with an initial block load applied to the generator, the computer will commence the loading of the boiler-turbine unit by direct digital control (DDC) on either or both the required output set point or boiler pressure set point of the co-ordinated analogue control equipment (refer to Appendix B ).

Based on plant measurements the computer determines the rate at which the set points are adjusted.

The maximum permissible rate of increase in output is set on the analogue control equipment. This limit will not be exceeded even if requested by the computer (this acts as an additional safe-

#### 4.5 DESCRIPTION OF CONTROL FUNCTION (CONT'D)

##### 4.5.4 Loading to a Pre-Set Target Load (Cont'd)

guard in the event of a computer malfunction.

A degree of operator participation is necessary during the loading phase to bring the pulverising mill groups and/or feed bumps in and out of service as dictated by the load and requested by the computer.

The operator is also required to select the target load and pressure and initiate the loading phase.

In the event of a malfunction in the co-ordinated analogue controls an alternative method of control is envisaged. In this alternative method the operator will control the boiler manually under computer guidance while the operator controls the generator loading gear.

Limitations on control will be throttle valve position.

The computer indicates to the operator when the target load has been achieved, at which point the operator transfers control to the co-ordinated analogue controls. This ends computer participation in the control function and the computer reverts to its plant monitoring and data logging role.

##### 4.5.5 Plant Abnormality Monitoring During Run-Up and Loading

During the computer controlled run-up and loading phase all critical parameters such as bearing vibration, differential casing movement, steam conditions, etc., are monitored by the control programme. Should any of these parameters fall outside certain pre-determined margins the programme will respond in one of four different ways, depending on the parameter and the degree to which it is in

#### 4.5 DESCRIPTION OF CONTROL FUNCTION (CONT'D)

##### 4.5.5 Plant Abnormality Monitoring During Run-Up and Loading (Cont'd)

discrepancy. The programme can call for a turbine trip, a reduction in speed or load, a speed or load hold, an increase in scan frequency of selected points, an alarm message.

A list of some of the monitored parameters and the action that will be taken is shown on page 52 to 55.

Should a fault cause a hold in speed or load, the control programme will re-accelerate the turbine or recommence loading automatically when the fault clears.

## ACTION TAKEN ON DETECTION OF PLANT ABNORMALITY

Test No.	Description	Cold Start			Hot Start			Abnorm. Limit	Remarks
		Run-Up	Load <200MW	Load >200MW	Run-Up	Load <200MW	Load >200MW		
1	Group 1 Conventional Alarm	Hold Speed	Hold Load	Hold Load	Hold Speed	Hold Load	Hold Load	-	Any of the following conventional alarms on i) Main Turbine Power Oil Pressure Low ii) Turbine Bearing Hot iii) Turbine Thrust Bearing Hot iv) Supervisory Supply Fail
2	Group 2 Conventional Alarm	Hold Speed	Hold Load	Hold Load	Hold Speed	Hold Load	Hold Load	-	Any of the following conventional alarms on i) Computer Power Supply Failed ii) Computer Hardware Failed
3	Group 3 Conventional Alarm	Hold Speed	Hold Load	Hold Load	Hold Speed	Hold Load	Hold Load	-	Any of the following conventional alarms on i) Exciter or Slipring CO <sub>2</sub> Released ii) Condenser Vacuum Failing iii) Stator Water Hot iv) Generator Hydrogen Hot
4	Group 4 Conventional Alarm	Rundown Speed	Rundown Load	Rundown Load	Rundown Speed	Rundown Load	Rundown Load	-	Conventional alarm Boiler tripped on
5	Group 5 Conventional Alarm	No Action	Hold Load	Hold Load	No Action	Hold Load	Hold Load	-	Any of the following conventional alarms on i) Exciter Air Hot ii) Auxiliary Board Voltage Low iii) Generator Transformer Winding Hot iv) Generator Transformer Buchholz v) Turbine Trip Circuit Supply Failed

ACTION TAKEN ON DETECTION OF PLANT ABNORMALITY (CONT'D)

[illegible]



[illegible]

ACTION TAKEN ON DETECTION OF PLANT ABNORMALITY (CONT'D)

Test No.	Description	Cold Start			Hot Start			Abnorm. Limit	Remarks
		Run-Up	Load < 200MW	Load > 200MW	Run-Up	Load < 200MW	Load > 200MW		
23	Valve Chest Inner/Outer Temperature Differential High	Hold Speed	Hold Speed	Increase Scan Rate of Monitored Variable	Increase Scan Rate of Monitored Variable	Increase Scan Rate of Monitored Variable	Increase Scan Rate of Monitored Variable	150°F to 240°F	Variable Limit
24	Bearing Oil Pressure Low	Rundown Speed	Hold Load	Alarm	Rundown Speed	Hold Load	Alarm	15 psig	
25	Boiler Pressure Low	Hold Speed	Rundown Load	Alarm	Hold Speed	Rundown Load	Alarm	400 psig	
26	Rate of Change of Boiler Pressure High	Hold Speed	Rundown Load	Alarm	Hold Speed	Rundown Load	Alarm	50 psig/min.	
27	Steam Mains Bifurcation Inner/Outer Temp. Diff. High	Hold Speed	Hold Load	No Action	Hold Speed	Hold Load	No Action	121°F to 213°F	Variable Limit

## 5 DESIGN FEATURES OF THE CONTROL PROGRAMME (FLOW CHARTS)

### 5.1 INTRODUCTION

The following section outlines some of the more important design features of the control programme (flowcharts).

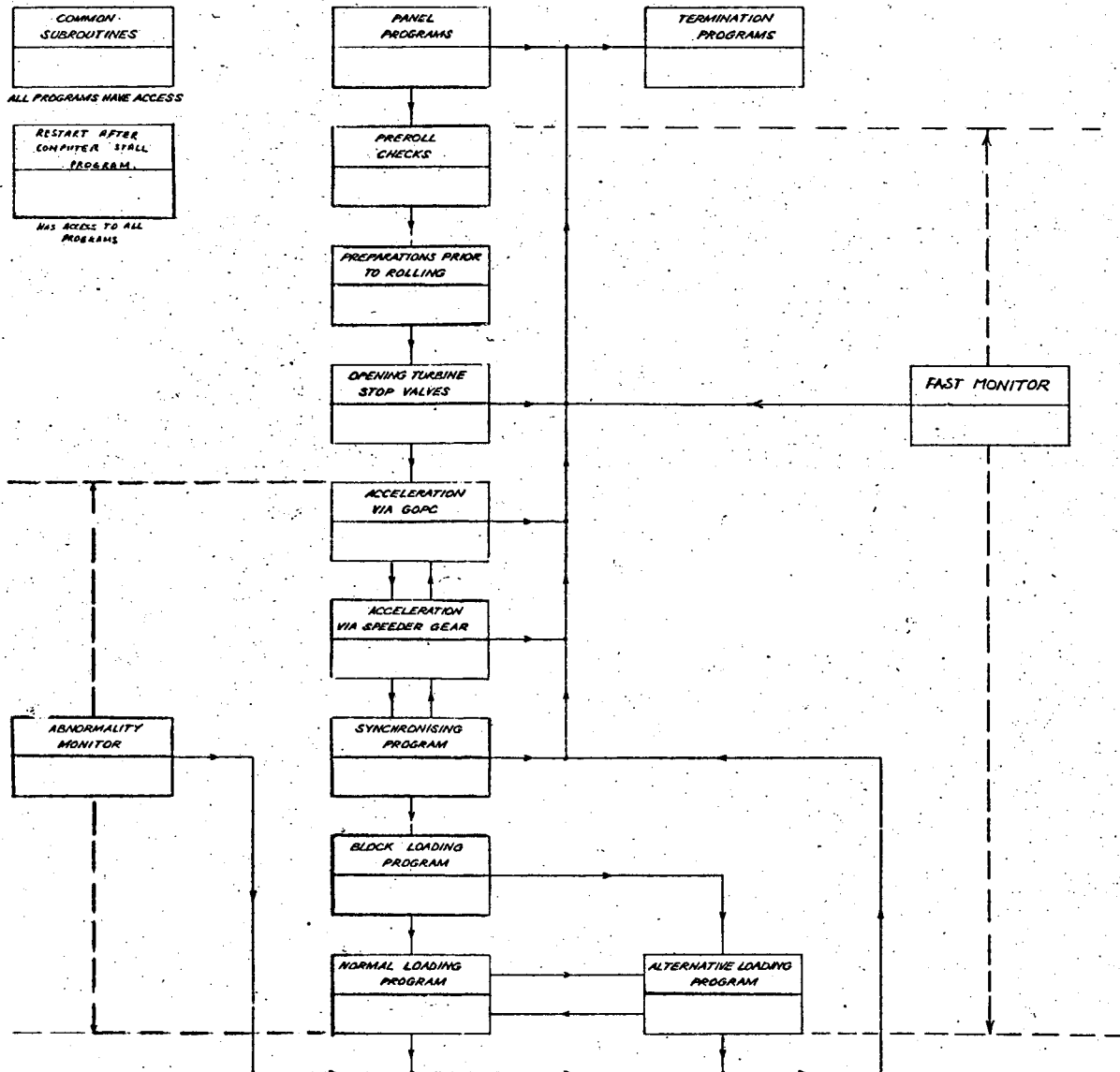
### 5.2 PROGRAMME (FLOWCHART) SEGMENTATION

The Liddell control programme (and flowchart) was segmented into a number of sub-programmes, each one, as far as possible, complete in itself and performing a specific function. The programme segmentation adopted is shown on page 57. This was done for the following reasons:

1. To reduce the size of core storage required for the control function (segmentation allows a long programme to run one piece at a time, thereby requiring only a fraction of the main memory it might have required unsegmented).
2. To permit changes in programmes as operating experience is accumulated without re-programming large sections of associated logic.

The linking of the sub-programmes is achieved through the GO TO PROGRAM statement in the SPL IV language (refer to section 10 ) and the NEXT PROGRAM symbol in the flowcharts (refer to Appendix M ).

The GO TO PROGRAM statement permits an executable programme to unconditionally transfer control to a second distinct executable programme which resides on disc memory. The programme transferring control does so unconditionally (or permanently) and as such when the programme transferred to is completed, control does not return to the programme which issued the GO TO PROGRAM statement.

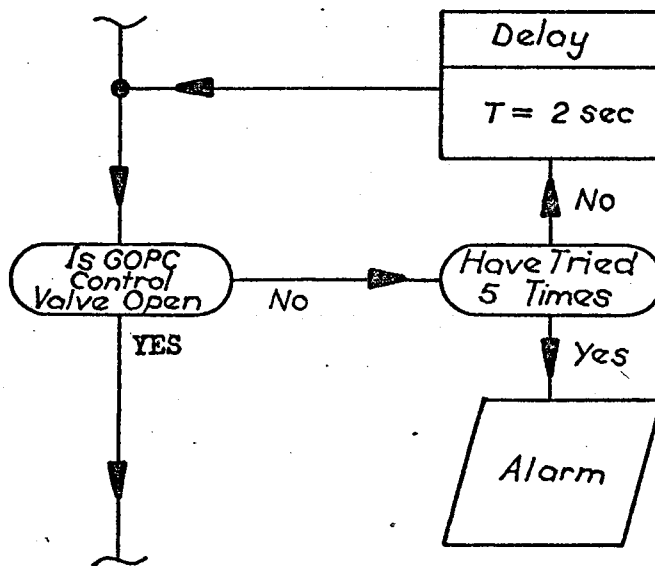


CONTROL PROGRAM SEGMENTATION

### 5.3 RE-ENTRY PHILOSOPHY

In the preparation of the (programme oriented) flow charts one of the major problems encountered was what to do on the occurrence of an alarm or where to return after an alarm condition had been cleared.

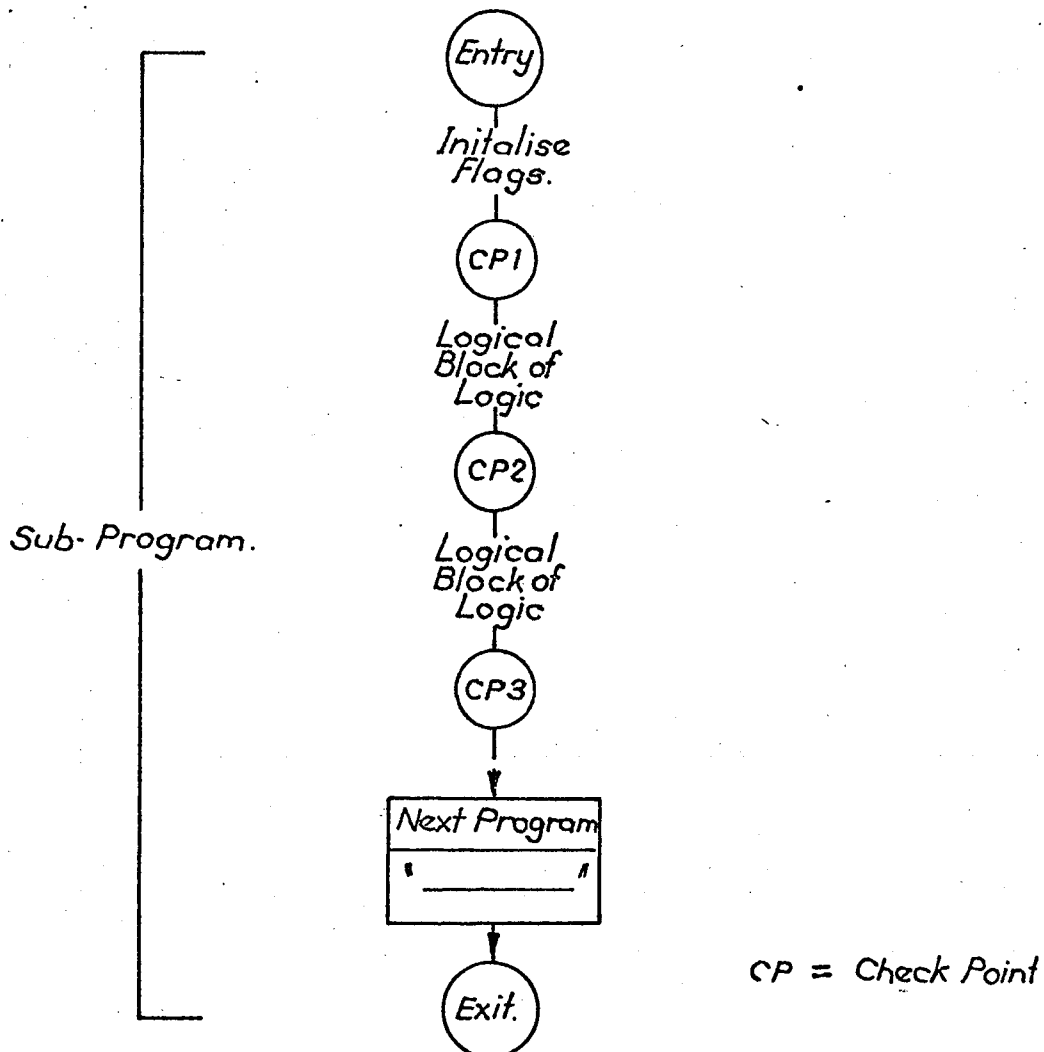
This problem is best illustrated by the following logic:



If after an alarm had been cleared we continued to the next step in the programme, sufficient time could have elapsed to allow some of the previous correct conditions to change. To overcome this problem required the programme to be re-entered after an alarm, at a sufficiently previous point to ensure safety. In preparing the programme oriented flow charts, this problem was solved by segmenting the sub-programmes into logical sections (blocks) by what is termed a "check point".

The following diagram illustrates how a sub-programme can be segmented into logical sections using check points.

### 5.3 RE-ENTRY PHILOSOPHY (CONT'D)



Between two check points of a sub-programme (or flow chart) normal sequence logic is specified. The logic between two check points, however, is treated as a single block for movement within the programme. In other words, all conditions within the block (between two check points) must be satisfied before the programme will continue to the next block (logical section).

The software system was designed to interrogate questions between the check points and if there are no alarms, the programme can progress to the next group. If an alarm condition did exist, the programme would not progress but would continue to interrogate the question and all previous questions until the condition is cleared or the operator overrides causing the programme to progress with the alarms not cleared.

### 5.3 RE-ENTRY PHILOSOPHY (CONT'D)

To prevent run back over large sections of the programme, the logical sections (blocks) should be kept as small as possible.

In conclusion, check points were added for two purposes:

- i) To specify that a group of checks all be satisfied before proceeding to the next logical sections.
- ii) To allow rechecking of previously satisfied conditions within a logical section.

### 5.4 MANUAL OVERRIDE FACILITY

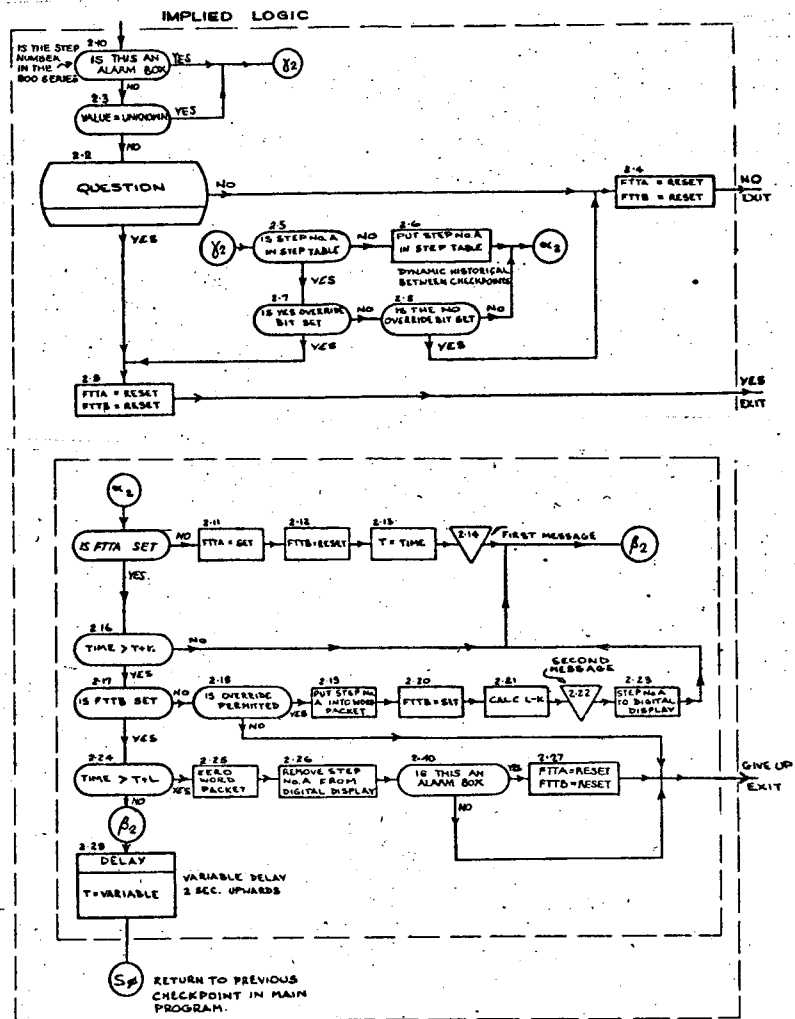
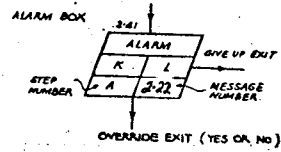
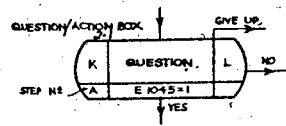
Another problem encountered was what to do when the progress through a programme is halted because the computer is unable to answer a question due to a faulty input. To overcome this problem, special logic was designed (as a subroutine) to allow an operator to answer a question (i.e. override the question) the computer is unable to answer because of faulty input thus allowing the sequence to continue.

The override question subroutine logic is shown on page 61 and functions as follows:

If the progress through a programme is halted because the answer to a question is unknown (due to faulty inputs) the computer produces a message which asks the operator to check the inputs to the question. After a time delay (variable from 2 seconds upwards) the control programme is re-entered at the previous checkpoint and all intervening logic is again re-checked until the particular question is again encountered. Hence, cyclic action is set up between the check point and the question box. If after some time "K" the question is still unknown, a second message is produced which tells the operator the override information [i.e. the step number for overriding this questions, the box number of the question (i.e. location of question on the flow charts), time allowed for the operator to take overriding action]. If the operator can determine through

#### 5.4      MANUAL OVERRIDE FACILITY (CONT'D)

### FLOW CHART REPRESENTATION





5.4 MANUAL OVERRIDE FACILITY (CONT'D)

observation, the answer to the question, and the run-up can safely continue, he can answer the question for the comOuter by dialing the step number on the digit wheels (on the turbine run-up control panel) and presses the "override yes" push button; otherwise he presses the "override no" push button. These buttons are also located on the turbine run-up control panel. If the question has not been overridden by some time "L" then the give up exit path is taken. The steps followed after the give up path is taken are shown on the flow charts.

The ability to inhibit the overriding of a question was also included in the logic.

The software design is such that if the answer to a previously known question (e.g. question No. 20.1) becomes unknown within the confines of the current check points while in the mode of cycling between a question further along the programme (e.g. question no. 20.6) and the check point, the programme will back up and honor the override logic of question no. 20.1. When question no. 20.1 clears and the programme advances to question no. 20.6, it is honored again as if it were the first time through.

The setting of the override, for a given question is retained provided you remain between the two check points. It is not necessary for the operator to set the override each time the question is executed. Entering the sub-programme at the beginning or moving to the next block will reset the overrides for questions within that block.

Logic was also designed to allow the operator to make a decision on the action required on the occurrence of some alarm conditions.

The alarm box logic (shown on page 61) functions as follows:

When the box is first entered an alarm message is produced. After a time "K" a second message is produced which tells the operator

#### 5.4      MANUAL OVERRIDE FACILITY (CONT'D)

the step number for overriding and the time allowed for the operator to take overriding action. If the operator dials the step number and presses either the "yes" or "no" push button on the control panel, the override path is taken. If the alarm box has not been overridden when time "L" expires, the give up exit is taken.

There is one major drawback to the above approach in that the operator is expected to read and understand the flow charts, so that he can determine the effect of the overriding action.

#### 5.5      HOLD/RESUME LOGIC

The control programmes were designed so that three types of "HOLD" functions could be implemented. They are as follows:

- i) An "operator requested hold" to be initiated and released via a control panel push button (refer to section 8 ).
- ii) An "abnormality hold" (requested when certain plant parameters exceed defined limits) to be initiated and released under programme control.
- iii) A "programme hold", to be initiated under programme control and released via the control panel push button.

The intent of the "operator requested hold" is to discontinue advancing the status of the power plant when plant conditions allow a hold to be respected safely. Hence, the question "Has hold been requested" is asked at all locations in the programme where a hold could take place safely.

If during a turbine run-up, for example, the operator requested a hold in the critical speed range, the logic in the flow charts was designed to cause a rundown in speed until we are out of the critical speed range, before holding the speed constant. The computer would then

### 5.5 HOLD/RESUME LOGIC

continue to perform the control actions necessary to hold the speed constant until cleared by the "RESUME" push button, on the control panel. On resumption, the programme is designed to enter a location given by the resume path.

The "abnormality hold" (requested when certain plant parameters exceed defined limits i.e. becomes abnormal) was also designed not to suspend the control programme immediately but to allow control action to continue until a hold can be respected safely. The "abnormality hold," however, can only be released when the plant parameter returns to normal. Refer to section 5.12 for a description of the plant parameter monitoring programme.

On executing the "programme hold" the logic is such that this programme only goes into an inactive condition until the operator presses the RESUME push button on the control panel. On resumption the programme is recalled with control being transferred to the location given by the resume path. This type of hold is specified in a programme at points where the flow chart designer may think the operator might need a delay or where the process requires one.

### 5.6 ORGANISATION OF CONTROL SUB PROGRAMMES

The control programmes were organised into three main groups, as follows:

- i) Panel Programmes which are initiated by the pressing of a push button on the turbine run up control panel (refer to section 8 ). These programmes do a specific task, and may initiate the running of sequential programmes.

## 5.6 ORGANISATION OF CONTROL PROGRAMMES (CONT'D)

- ii) Sequential programmes which are used for the majority of the control tasks. Each programme deals with a specific area of control (e.g. accelerating the turbine via the speeder gear) and when its task is completed, calls the next sequential programme into action.)
- iii) Monitoring Programmes which run in parallel to the main sequential programme. If they require control action to be carried out (e.g. reduction in turbine speed) they signal this to the running sequential programme which carries out the control action on the plant.

All programmes, once commenced, run on a periodic basis with the period for the re-run initiated via a time delay. Each sequential programme on completion of its task calls the next programme into action.

The interface between the monitoring programmes and the sequential programmes is handled by having the monitoring programmes set flags which are tested by the sequential programmes.

All push button lights on the control panel are controlled by the panel programmes. The indicating lights are controlled by either the panel programmes, or sequential programmes. A block diagram of the control programmes is shown on page 57 .

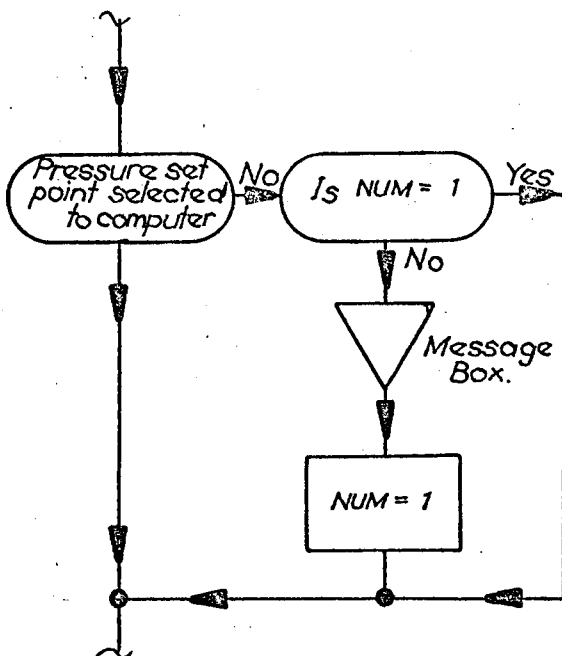
## 5.7 MESSAGE GENERATION SUB-SYSTEM

In the early design stage of the control flow charts it was realised that if messages requesting an action to be carried out by the operator are printed at too frequent intervals, the human operator would tend to become antagonised. To prevent an unwanted number of messages being produced, logic was added to the flow charts to indicate if a message was to be printed.

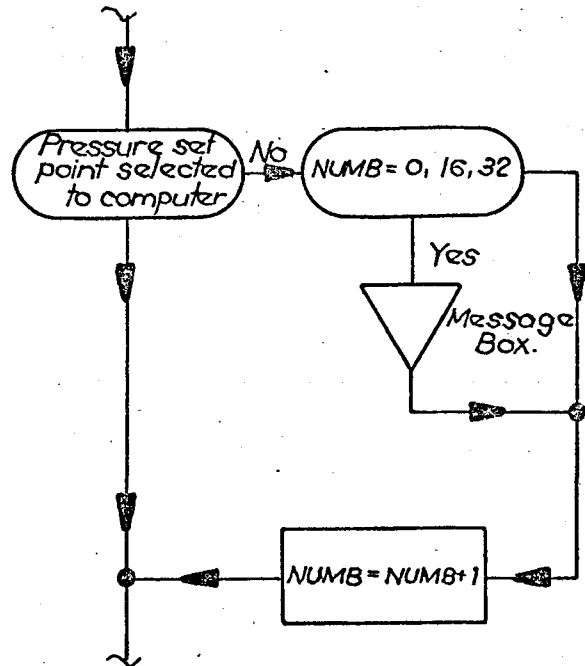
## 5.7 MESSAGE GENERATION SUB-SYSTEM (CONT'D)

- i) only once on the first pass through the programme,
- or ii) every x times (e.g. once a minute) the programme is run as long as the condition exists.

A sample of the logic used to implement this function is shown below:



TYPE 1  
MESSAGE



TYPE 2  
MESSAGE

Since the control programmes were to be written in SPL IV (refer to section 10 for a description of the programming language), the control messages were expected to be handled through the Fortran write statement.

However, during the programming phase, the computer Contractor found that the Fortran message printing system could not handle the large volume of control messages on a per programme basis (because the Format Editor logic was carried by each sub-programme using the Fortran WRITE statement). For this reason a special message handling system was designed with the following advantages:

## 5.7 MESSAGE GENERATION SUB-SYSTEM (CONT'D)

1. A substantial reduction in the size of the control sub-programmes.
2. The control message handler runs independently (at a lower priority) to the control sub-programmes.
3. The message text (pre-stored in auxiliary memory) could be changed manually instead of by a programme recompilation.
4. Messages designated for printout can contain both static information and dynamic values of system variables.

The system was sized for 999 control messages; currently there is about 30% spare capacity.

Sample control messages are shown below.

- a) START UP UNSUCCESSFUL - UNKNOWN IF CPU DISCONNECTED VIA EMERGENCY DISABLE PUSH BUTTON
- b) COMPUTER HOLD, UNKNOWN IF GOPC CONTROL VALUE SET TO COMPUTER.
- c) PLEASE PRESS START LOADING PUSH BUTTON
- d) START TYPE = (hot, cold, warm)  
 TARGET LOAD = (0-500) MW  
 TARGET PRESSURE = (600-2400) PSIG  
 ESTIMATED LOADING TIME = (x) MINUTES

Control message (d) contains dynamic values as determined by the control programme.

## 5.8 SCAN FREQUENCY OF CONTROL INPUTS

In order to provide closer monitoring of analogue inputs during the control function, the control sub-programmes were to be designed such that the first step on entering a sub-programme would be to

## 5.8 SCAN FREQUENCY OF CONTROL INPUTS (CONT'D)

increase the scan frequency of inputs used in that sub-programme. Progress to the next step in the sub-programme was to be inhibited until this function was completed. The scan frequency changer programme supplied with the basic system, however, made only one scan frequency change per two seconds. The Commission considered this slow rate would cause undesirable delays during the control function.

To overcome the problem it was decided that prior to commencing the control function a request would be made to increase the scan frequency of all control inputs.

If the automatic turbine recovery function was implemented at Liddell a scan frequency change rate of at least 40 inputs per 2 seconds would be required.

When an input is placed on control scan frequency by the control programme, the operator cannot manually override this, from the man computer communication panel.

When computer control is terminated all control inputs are returned to normal scan frequency.

Refer to Appendix H for the normal and control scan frequency of inputs to the control programme.

## 5.9 INTEGRITY OF CONTROL INPUTS

The computer system software at Liddell is designed to carry out transducer validity checking just after scanning the input and the value read is marked with a quality code (good or bad). An input value is declared bad if the input signal is outside the range of the analogue-to-digital converter, if a thermocouple open circuit is detected or if the input signal is outside the valid range for that particular type of transducer.

## 5.9 INTEGRITY OF CONTROL PARAMETERS (CONT'D)

Overseas experience has shown that if inputs to control programmes are single inputs the operator would be continually overriding bad inputs resulting in delays in the run-up period and loss of confidence in the system.

One method of overcoming this problem is to duplicate all control inputs. Because of the cost of additional transmitters and cabling, however, the Commission decided that only key control parameters (e.g. turbine speed) would be duplicated.

Calculation routines were designed to determine the most likely value (i.e. Believed Value) of the variable to be used in the control programmes. These routines were designed to interrogate the quality of inputs and delete it from the calculation if found bad. If all inputs are found bad, the result of the calculation routine is declared bad (i.e. unknown).

## 5.10 "BELIEVED VALUE" LOGIC

### a) Analogue "Believed Value" Logic

In trying to determine the best logic for calculating the most likely value ("Believed Value") of an important plant parameter from three or more independent measurements, a number of different mathematical routines were investigated. The first routine investigated had the following features:

- i) The "Believed Value" was derived as the average of two of the analogue values. The selected two were those having the least difference in magnitude.
- ii) Inputs to the computation were deleted if they were outside their transducer range or taken out of scan (i.e. declared bad by the validity checking programme).



5.10 "BELIEVED VALUE" LOGIC (CONT'D)

- iii) Any input that differed from the "Believed Value" by more than some preset amount was alarmed.

The major problem encountered with this routine was that a step change in value could occur when one component value is suddenly declared bad by the input validity check programme or the input deviates widely.

Another routine investigated involved the ordering of the differences between inputs. Pairs of inputs which were close in value were weighted very heavily with the degree of weighting decreasing rapidly until the pair of inputs with the largest difference received only very slight weighting in the weighted average routine to give the "Believed Value" for the input set.

Two weighting systems were investigated as follows:

- i) A weighting system proportional to the inverse of the distance of the separation between inputs.
- ii) A weighting system proportional to the inverse of the square of the distance of separation between inputs.

The weighting system which gave the best overall result was ii) and the flow chart logic is shown on page 72.

The following table is an example of the results of the "Believed Value" routine for three analogue inputs compared with the simple average routine.

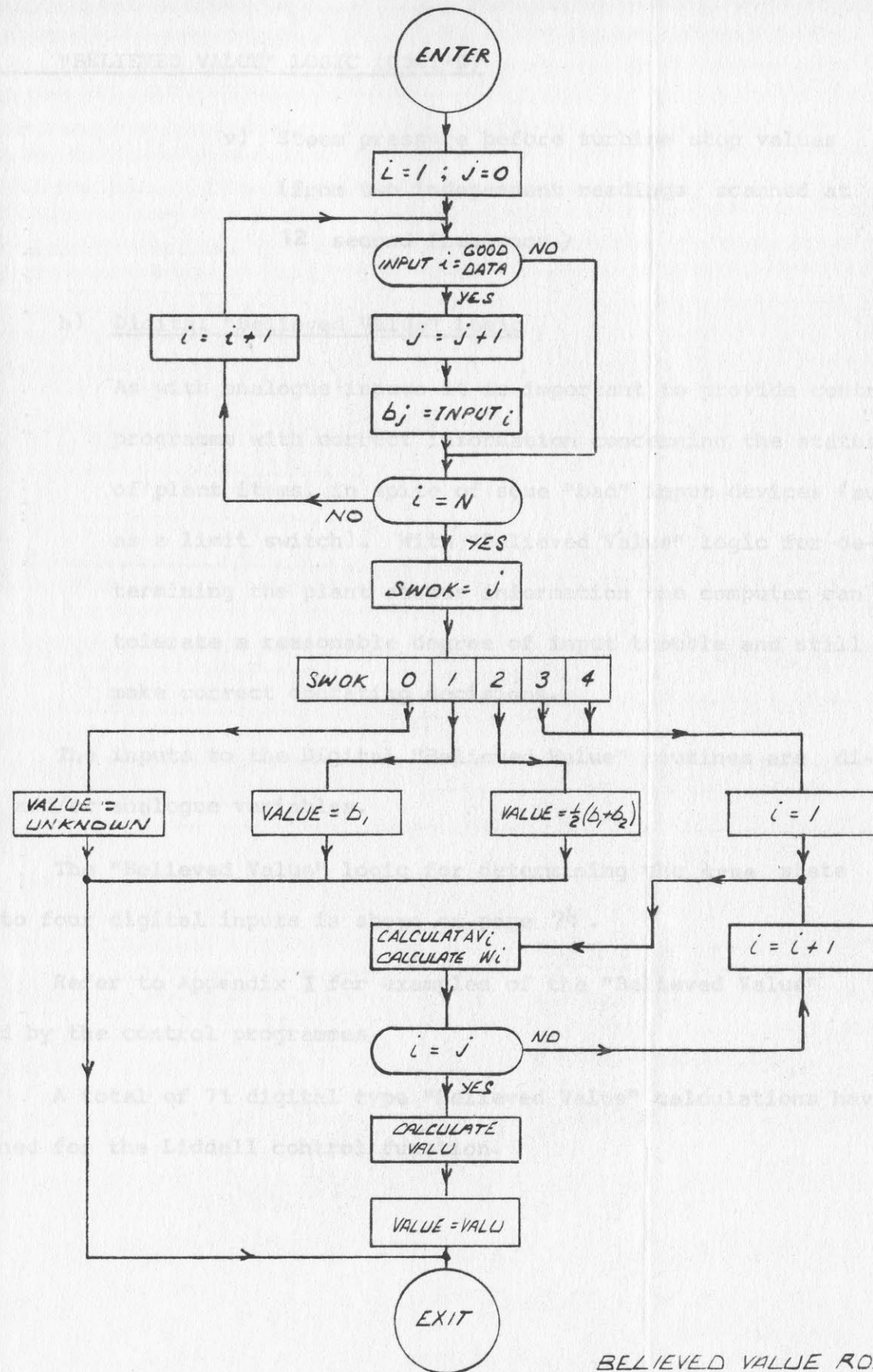
## 510 "BELIEVED VALUE" LOGIC (CONT'D)

## BELIEVED VALUE

A	B	C	M=1	M=10	M=100	AVG
9.00	8.00	7.00	8.0025	8.0146	8.0256	8.0000
.90	.80	.70	.8000	.8003	.8015	.8000
.09	.08	.07	.0800	.0800	.0800	.0800
-9.00	8.00	7.00	7.5538	7.5110	7.5067	2.0000
-9.00	-8.00	7.00	-8.5419	-8.4992	-8.4949	-3.3333
-9.00	-8.00	-7.00	-7.9976	-8.1495	-8.0304	-8.0000
1.00	1.00	.50	.8500	.9211	.9862	.8333
.10	.10	.05	.0835	.0850	.0921	.0833
1.00	.50	.50	.6500	.5789	.5138	.6667
1.00	1.00	.10	.7988	.9492	.9940	.7000
1.00	1.00	.01	.7996	.9558	.9950	.6700
1.00	.10	.10	.3012	.1508	.1060	.4000
1.00	1.50	.50	1.0100	1.0391	1.0534	1.0000
2.00	1.50	1.50	1.5045	1.5224	1.5348	1.5000
4.00	3.50	3.00	3.5008	3.5061	3.5138	3.5000
6.00	6.50	7.00	6.5002	6.5021	6.5066	6.5000
.00	-1.00	-2.00	-2.2000	-1.2431	-1.2242	-1.0000
-1.00	-2.00	.00	-2.2000	-1.2431	-1.2242	-1.0000

The analogue "Believed Value" routine was used for determining the value of eight plant parameters. For example, the following variables were calculated using this routine.

- i) Turbine Speed (from three independent speed readings scanned in close succession at 2 second frequency)
- ii) No. 2 throttle value position (from two independent readings scanned in close succession at 6 second frequency)
- iii) Steam temperature before turbine throttle values (from four independent readings) scanned at 12 second frequency).
- iv) Unit Load (from two independent readings) scanned at 6 second frequency).



$SWOK = 3$

$i$	$AV_i$	$\Delta i$
1	$\frac{b_1 + b_2}{2NLF}$	$\frac{b_1 - b_2}{NLF}$
2	$\frac{b_2 + b_3}{2NLF}$	$\frac{b_2 - b_3}{NLF}$
3	$\frac{b_3 + b_1}{2NLF}$	$\frac{b_3 - b_1}{NLF}$

$SWOK = 4$

$i$	$AV_i$	$\Delta i$
1	$\frac{b_1 + b_2}{2NLF}$	$\frac{b_1 - b_2}{NLF}$
2	$\frac{b_2 + b_3}{2NLF}$	$\frac{b_2 - b_3}{NLF}$
3	$\frac{b_3 + b_4}{2NLF}$	$\frac{b_3 - b_4}{NLF}$
4	$\frac{b_4 + b_1}{2NLF}$	$\frac{b_4 - b_1}{NLF}$

$$W_i = \frac{1}{1 + M \left( \frac{\Delta i^2}{AV_i} \right)} \quad ; M = 100$$

$$VALU = \left( \frac{\sum_{i=1}^j AV_i \times W_i}{\sum_{i=1}^j W_i} \right) \times NLF$$

### NOTES

- $N = N^{\circ}$  OF INPUTS
- $NLF =$  NORMALISING FACTOR WHICH DESIGNATES THE BAND OF REASONABLE VARIATION.
- $M =$  CONTROLS THE DEGREE OF WAITING

BELIEVED VALUE ROUTINE FOR 1-2-3-4 ANALOG INPUTS.

AMENDMENTS	DRAWN					
	CHECKED					
					SCALE	
					DATE	
						AMD

D

- v) Steam pressure before turbine stop values  
(from two independent readings scanned at  
12 second frequency.)

b) Digital "Believed Value" Logic

As with analogue inputs it is important to provide control programme with correct information concerning the status of plant items, in spite of some "bad" input devices (such as a limit switch). With "Believed Value" logic for determining the plant status information the computer can tolerate a reasonable degree of input trouble and still make correct operating decisions.

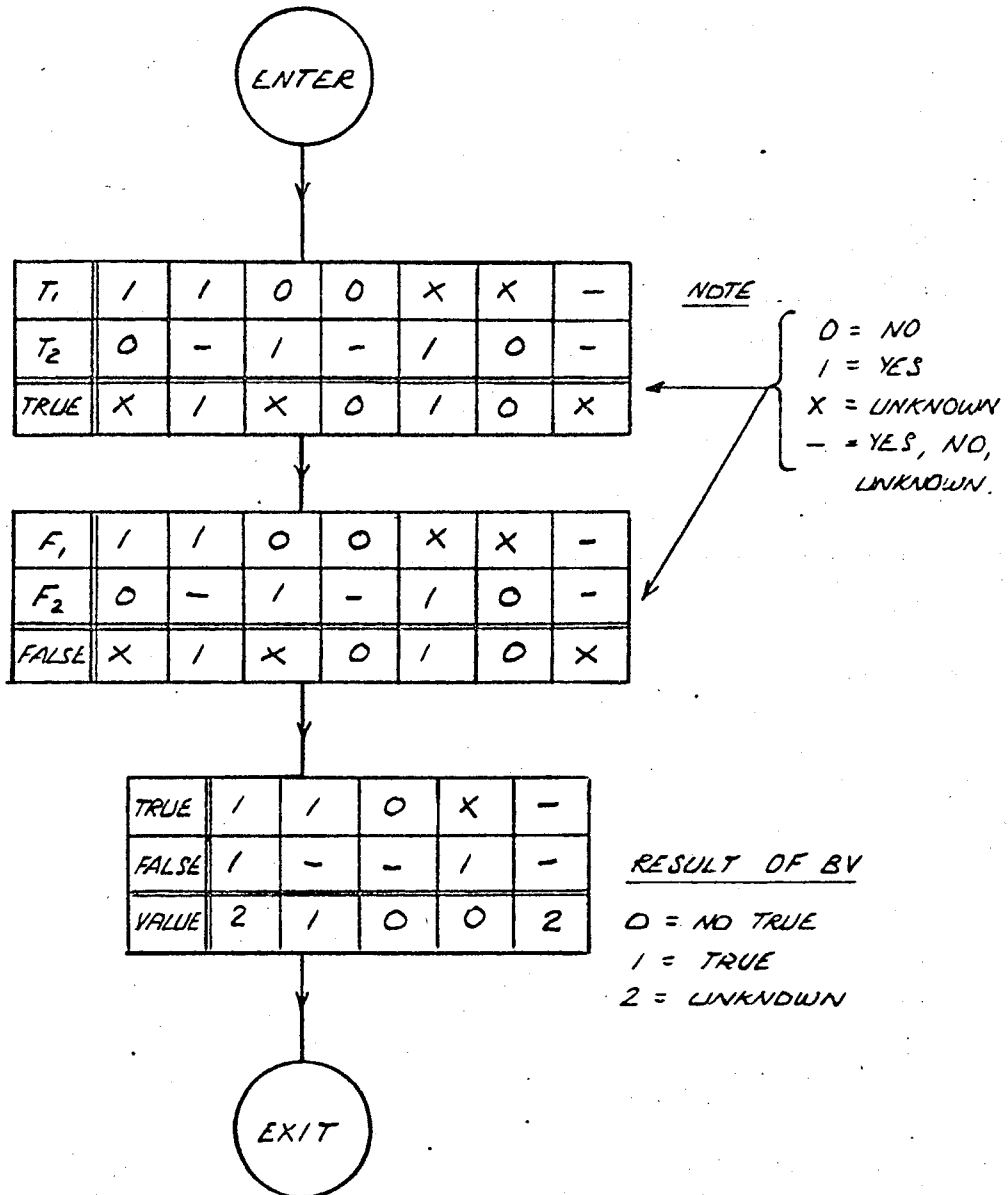
The inputs to the Digital "Believed Value" routines are digital and/or analogue variables.

The "Believed Value" logic for determining the true state from one to four digital inputs is shown on page 74.

Refer to Appendix I for examples of the "Believed Value" logic used by the control programmes.

A total of 71 digital type "Believed Value" calculations have been defined for the Liddell control function.

## 5.10 "BELIEVED VALUE" LOGIC (CONT'D)

NOTES

INPUTS T<sub>1</sub> & T<sub>2</sub> = 1 IF TEST IS TRUE  
(T<sub>2</sub> IS CONFIRMING INPUT)  
INPUTS F<sub>1</sub> & F<sub>2</sub> = 1 IF TEST IS FALSE  
(F<sub>2</sub> IS CONFIRMING INPUT)

BELIEVED VALUE ROUTINES FOR 1-2-3-4 DIGITAL INPUTS

5.11 "BELIEVED VALUE" COMPUTATION

The initial design concept was to evaluate the "Believed Value" of a variable via a sub-routine upon entry to a question box.

However, the contractor felt that when several "Believed Values" required checking between any two successive check points unnecessary drum traffic would occur. This increase in drum transfers during automatic turbine run up would not have been prohibitive, but was considered extremely wasteful and could noticeably lengthen response time. To reduce the drum traffic the contractor suggested to evaluate the "Believed Values" on a periodic basis, as a basic system calculation. The control programme would then get the value of such calculations from the analogue data field.

The Contractor in the early design stage also informed the Commission that the system was such that the value of calculations performed within the control programmes could not be requested from the man computer Communication Panel (later design changes to the software system now enable inline calculations to be reported from the panel).

The Commission was against calculating the "Believed Value" routine periodically in the basic system because control decisions could be based on out of date data. In addition the Commission believed strongly that the operator must be able to request the result of any "Believed Value" calculation and also have the ability to trend the value on a trend recorder.

However, since any software modification to the system at that stage could have caused unacceptable delays in the delivery of the computer system (which was required for commissioning the boiler/turbine unit) the Commission agreed to calculate "Believed Value" routines periodically in the basic system.

The basic system calculation programmes are scheduled on a periodic basis by the executive programme. Their frequencies of running

### 5.11 "BELIEVED VALUE" COMPUTATION (CONT'D)

are 2 seconds, 6, and 12 seconds. The calculation programme computes the dependent variables as specified, using the latest data acquired by the analogue input scanning and processing subsystem.

### 5.12 PLANT PARAMETER MONITORING PROGRAMME

The principal function of this programme was to compare parameters such as bearing vibration, eccentricity, temperature gradients, etc., with preset limits and if these are exceeded to initiate the appropriate action. The conventional alarms were also to be monitored by this programme and the appropriate action taken if detected in the alarm state.

If an abnormality is detected one of five corrective actions were to be catered for. They are as follows in order of priority.

- i) Turbine trip (by closing the turbine stop valves)
- ii) Speed or load runback (by closing the throttle valves)
- iii) Holding speed or load constant
- iv) Increasing scan frequency of steam temperature inputs
- v) Alarm but continue.

The initial design concept was to initiate the programme when the automatic turbine run-up operation commenced and from then on the programme was to run periodically at a one second frequency. However, the computer contractor felt that running this programme every one second would tax the computer too heavily and suggested relaxing the requirement to six seconds.

The Commission felt that six seconds was too slow, and put forward the following alternative which was accepted by the computer Contractor.

5.12 PLANT PARAMETER MONITORING PROGRAMME (CONT'D)

The abnormality monitor programme would be designed to run normally at a six second frequency. However, during times of system disturbance (detected by one of the conventional alarms going into the alarm state) the conventional alarms are to be checked every one second.

Additional design features of this programme are as follows:

- i) Counting logic was included to ensure that all readings are confirmed prior to taking any action (this was to prevent spurious trips on occurrence of a noise on an input).
- ii) All inputs to the programme are of the digital form (refer to page 52 for the list) and are calculated in the basis sytem and passed to this programme as required. The calculations are event triggered (i.e. when one of the inputs changes state or exceeds a limit) and not periodically triggered.
- iii) On detection of an abnormality of one input we do not give up monitoring other inputs to the programme. This is because some other input would be calling for a trip.
- iv) If more than one input is calling for a corrective action, the higher priority action is initiated first.
- v) If an abnormality exists which is calling for a trip, the programme will initiate the trip.
- vi) If an abnormality exists which is calling for a hold or rundown control action, a flag is set which is monitored by the running sequential programme which carries out the control action on the plant.



5.12 PLANT PARAMETER MONITORING PROGRAMME (CONT'D)

Appendix J shows the flow chart for the abnormality monitor programme.

5.13 LOGIC TO OPERATE PLANT EQUIPMENT TO A LIMIT

In the control function proposed, a number of items of plant were required to be driven to a limit by the computer. The limit was to be detected by a switch and could indicate a fully open, half open, or closed position. To implement this requirement a special sub-routine was designed the logic of which is shown on page 79.

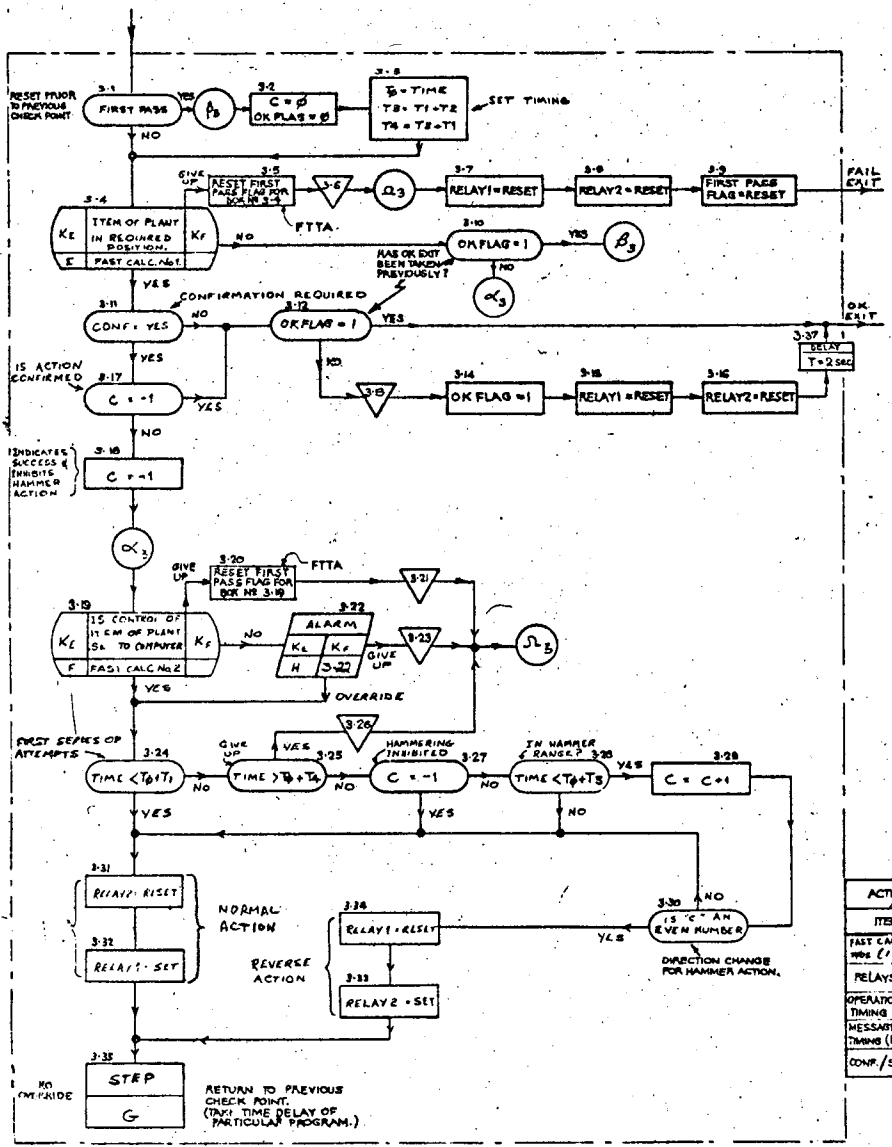
The sub-routine functions as follows:

When called this sub-routine closes the relay to fully open a valve say. If after a time "T" the valve is not open, the computer initiates a close/open series of pulses (called a hammer action) for a period of time " $T_2$ " before trying to open the valve again. If the computer fails to open the valve after a period of time " $T_4$ " the fail exit path is taken.

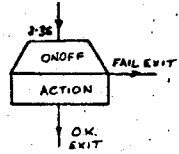
The "operate plant to limit" sub-routine was used to:

- i) run the speeder gear to the minimum position.
- ii) open the G.O.P.C. isolating valve fully.
- iii) open the G.O.P.C. control valve fully.

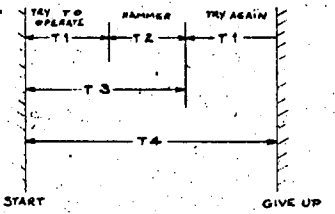
IMPLIED LOGIC.



FLOW CHART REPRESENTATION



TIMING.



DATA TABLE DETAILS.

ACTION	(e.g. RUN SPEEDER GEAR TO MINIMUM POSITION)	
ITEM	(e.g. SPEEDER GEAR)	
FAST CALC. NO. 1 (1/2)	(e.g. 21041)	FAST CALC. NO. 1 = 1 WHEN ACTION IS SUCCESSFUL
RELAYS (1/2)	(e.g. K0063) (e.g. K0064)	FAST CALC. NO. 2 = 1 WHEN CONTROL OF ITEM IS SET TO COMPUTER
OPERATION TIMING (T1/2)	(e.g. 3 mins) (e.g. 20 secs)	RELAY 1 = SET GIVES ACTION
MESSAGE TIMING (K1/2)	(e.g. 2 mins) (e.g. 6 mins)	RELAY 2 = SET GIVES REVERSE ACTION
CONF. / STEPS	(e.g. YES AND NO) (e.g. 15-12, 22)	SEE TIMING DETAILS ABOVE TABLE
		K1 = TIMING BETWEEN MESSAGES
		K2 = TIME TO GIVE UP
		YES = ONE EITHER OPERATION TO BE DONE AFTER STEP 2 = STEP NUMBERS 15-14

NOTES

C is success indicator plus hammer action pointer.  
If C = -1 plant is in required position and no hammer is required.  
If C > -1 hammering may take place.

MESSAGES.

- 3-5 - (Fast Calc No. 1) (Item) Position unknown.
- 3-15 - Computer Action (Action) successful.
- 3-21 - Unknown if (Item) set to computer control.
- 3-23 - (Item) not set to computer control.
- 3-25 - Computer attempt to (Action) unsuccessful.
- 3-22 - Alarm (Item) not set to computer control, may be overridden by Step No. H.

STEP MESSAGES.

- STEP E - SGA (FAST CALC. NO. 1) (INPUT NO. 1)
- STEP F - SGA ((ITEM OF PLANT) IS IN REQUIRED POSITION) (BOX 3-4) (STEP E)
- STEP F - SGA ((FAST CALC. NO. 2) (INPUT NO. 2))
- STEP G - NO MESSAGE
- STEP H - ALARM (ITEM OF PLANT) NOT SET TO COMPUTER CONTROL.

USED FOR MESSAGES.

5.14 ENTERING THE CONTROL PROGRAMME AT ANY POINT

This feature was required in connection with recommencing control after a computer stall (of short duration) and is also required if an automatic turbine recovery function is to be implemented (proposed but not implemented at Liddell).

To accomplish this feature a sequence monitor flag WHERE is set on entry to each control sub-programme. The WHERE flag has the following values:

- 0 = COMPUTER CONTROL STOPPED
- 1 = START UP GRANTED
- 2 = PREROLL CHECK PROGRAM
- 3 = PREPARATION PRIOR TO ROLLING
- 4 = OPENING TURBINE STOP VALVES PROGRAM
- 5 = ACCELERATION VIA G.O.P.C. PRIOR TO CALC. OF LOADING PARAM.
- 6 = ACCELERATION VIA G.O.P.C. AFTER CALC. OF LOADING PARAMETERS
- 7 = ACCELERATION VIA SPEEDER GEAR
- 8 = SYNCHRONISING PROGRAM
- 9 = BLOCK LOADING PROGRAM
- 10 = NORMAL LOADING PROGRAM
- 11 = ALTERNATIVE LOADING PROGRAM

A programme running periodically (at one second frequency) sets a flag HOPE = WHERE and stores the value of HOPE and INSURE (=123-HOPE) away in auxiliary memory. INSURE is a check word used to insure that the HOPE value has not been damaged due to the computer stall. The flag HOPE represents the control sub-programme last entered.

After an automatic restart a programme is called which checks if HOPE has been damaged (i.e.  $\text{HOPE} + \text{INSURE} = 123$ ). If not damaged, the programme then proceeds to check the plant conditions to see whether control can be returned to the stage it was at prior to the computer

5.14 ENTERING THE CONTROL PROGRAMME AT ANY POINT (CONT'D)

stall (represented by HOPE). If control restart is feasible the computer calls the appropriate programme which was running before the computer stall occurred.

5.15 PLANT PROTECTION AGAINST COMPUTER FAILURE

When controlling the plant, safety checks are provided through the software and hardware to ensure against the generation of false control commands.

The system was designed such that computer control is disabled when:

- a) A serious system error is detected by the software which necessitates a system restart or a system shut down.  
All digital outputs will be de-energised (open) via software.
- b) A computer stall condition is detected by the dead system timer and its interrupt. The dead system timer interrupt causes a serious error so that all digital outputs will be opened per a) above.
- c) A power supply failure is detected. The power failure detection hardware and its interrupt will also signal a serious system error which will open the output relays just before the powerloss is felt by the relay.
- d) The emergency disable push button which is located on the turbine run-up control panel is operated. The group selection relays either connect or disconnect the output relays when the emergency disable push button is operated (Refer to Appendix K ).

## 6. DIRECT DIGITAL CONTROL SUBSYSTEM

### 6.1 GENERAL

The Direct Digital Control (DDC) subsystem consists of a controller programme, and one output channel for each controlled variable.

The basic function of the controller programme is to calculate the incremental change in position of the controlling end element required to maintain the process at the desired value.

To accomplish this, the necessary incremental change (a function of the difference between desired value (set point) and the controlled variable) is calculated once per control interval (which may be 1 to 6 seconds in length).

For each control loop there is a set of controller parameters which may be modified on-line either manually or by program control. For example, if a figure for proportional gain is entered, the selected control loop will now have proportional action.

The controller programme uses a control algorithm or computing procedure in which gain, reset and rate have the same significance as with conventional analogue controllers. However, the programme has an advantage in that its gain may be varied to obtain tight control over a wide range of plant operating conditions.

The control programs switch individual control DDC loops to auto and manual when required. In case of system

6.1 GENERAL (CONTD.)

malfunctions, such as computer power supply failure or loss of control inputs, loops will be transferred automatically from auto to manual control.

6.2 USE OF DIRECT DIGITAL CONTROL

Direct Digital Control (DDC) is used at Liddell on the following four items of equipment.

- (i) G.O.P.C. control valve actuator
- (ii) Turbine speeder gear motor
- (iii) Required output set point of the boiler analogue control equipment.
- (iv) Boiler pressure set point of the boiler analogue control equipment.

The six control loops at Liddell are the governed oil pressure control valve speed reference, speeder gear speed reference, speeder gear load reference, speeder gear pressure reference, pressure set point servo and required output set point servo reference.

## 6.2 USE OF DIRECT DIGITAL CONTROL (CONTD.)

The following table summarises the variables controlled and device regulated by DDC:

CONTROL CHANNEL	FINAL CONTROLLED VARIABLE	VARIABLE CONTROLLED BY DDC	DEVICE REGULATED BY DDC	SET POINT GIVEN TO DDC PROGRAMME
G.O.P.C. Control Valve	Actual Turbine Speed	Actual Turbine Speed	G.O.P.C. Control Valve Actuator	Desired Turbine Speed (GOPCREF)
Speeder Gear	Actual Turbine Speed	Actual Turbine Speed	Speeder Gear Motor	Desired Turbine Speed (SPDGSREF)
	Actual Load	Actual Load	Speeder Gear Motor	Desired Turbine Load (SPDGLREF)
	Actual Load	Throttle Steam Pressure	Speed Gear Motor	Desired Pressure (SPDGPREF)
Throttle Pressure	Throttle Steam Pressure	Pressure Set Point	Pressure Set Point Servo	Desired Pressure Set Point (PSPREF)
Required Output	Load	Required Output Set Point	Required Output Set Point Servo	Desired Required Output Set Point (ROSPREF)

### 6.3 CONTROL ALGORITHM

To allow the use of established tuning procedures L & N decided that the digital form of the control algorithm should be equivalent to the analogue controller.

Most analogue controllers can be approximated by the transfer function:

$$\frac{M(S)}{e(S)} = K_p \left[ 1 + \frac{1}{T_i S} \right] \left[ 1 + T_d S \right] \quad - (1)$$

where:

- $K_p$  = controller gain
- $T_i$  = integration (reset) time constant
- $T_d$  = differentiation (rate) time constant
- $M(S)$  = controller output
- $e(S)$  = control error

Expressing equation (1) as the sum of proportional, integral and derivative terms we get

$$\frac{M(S)}{e(S)} = K_p \left[ \left( 1 + \frac{T_d}{T_i} \right) + \frac{1}{T_i S} + T_d S \right] \quad - (2)$$

However, most analogue controllers filter the error signal before taking its derivative for the purpose of noise attenuation.

Including the derivative filter in equation (2) we get

$$\frac{M(S)}{e(S)} = K_p \left[ \left( 1 + \frac{T_d}{T_i} \right) + \frac{1}{T_i S} + \left( \frac{T_d S}{1 + \frac{T_d}{G} S} \right) \right] \quad - (3)$$

where:

- $G$  = derivative filter factor (rate gain)

Expressing equation (3) as a set of equations we have

$$M(S) = P(S) + I(S) + R(S) \quad - (4)$$



where:

$$P(S) = K_p \left[ 1 + \frac{T_d}{T_i} \right] e(S)$$

$$I(S) = \frac{K_p}{T_i S} * e(S)$$

$$R(S) = \frac{K_p T_d S}{\left(\frac{T_d}{G}\right)S + 1} * e(S) = \left[ \frac{-G}{T_d} \frac{R(S)}{S} + G e(S) \right]$$

In the time domain we get

$$P(t) = K_p \left( 1 + \frac{T_d}{T_i} \right) e(t)$$

$$I(t) = \frac{K_p}{T_i} \int e(t) dt$$

$$R(t) = \frac{-G}{T_d} \int R(t) dt + G e(t)$$

If the error is sampled at an interval  $T_s$  then using finite differences we get:

$$\begin{aligned} \Delta M_n &= M_n - M_{n-1} & -(5) \\ &= \Delta P_n + \Delta I_n + \Delta R_n \end{aligned}$$

where

$$\Delta P_n = P_n - P_{n-1} = K_p \left( 1 + \frac{T_d}{T_i} \right) (e_n - e_{n-1})$$

$$\Delta I_n = I_n - I_{n-1} = \frac{K_p T_s}{2 T_i} (e_n + e_{n-1}) \quad \text{using trapezoidal integration method}$$

$$\Delta R_n = R_n - R_{n-1}$$

Now

$$R_n(t) = \frac{-G}{T_d} \int R_n(t) dt + G e_n$$

using trapezoidal integration method

$$R_n = \frac{G T_s}{T_d} \sum_{n=-\infty}^n \frac{D_n + D_{n-1}}{2} + G e_n$$

### 6.3 CONTROL ALGORITHM (CONT'D)

subtracting  $R_{n-1}$  from both sides:

$$R_n - R_{n-1} = \frac{-GT_s}{T_d} \left( \frac{R_n + R_{n-1}}{2} \right) + G(e_n - e_{n-1})$$

$$\therefore R_n = \frac{2T_d G}{2T_d + GT_s} (e_n + e_{n-1}) + \frac{2T_d - GT_s}{2T_d + GT_s} R_{n-1}$$

$$\begin{aligned} \therefore \Delta R &= R_n - R_{n-1} \\ &= \frac{2T_d G}{2T_d + GT_s} (e_n - 2e_{n-1} + e_{n-2}) + \frac{2T_d - GT_s}{2T_d + GT_s} \Delta R_{n-1} \end{aligned}$$

This expression for the incremental rate action has the disadvantage that a change in set point will cause a rate "kick". To avoid this  $(2I_{n-1} - I_n - I_{n-2})$  is substituted for  $(e_n - 2e_{n-1} + e_{n-2})$ .

$$\text{where } e_n = SP - I_n$$

$I$  = actual value of the variable

$SP$  = set point (desired value of variable)

If the set point remains constant, this substitution will have no effect on the amount of rate action.

The control algorithm then becomes:

$$\Delta M_n = K_p \left( 1 + \frac{T_d}{T_i} \right) (e_n - e_{n-1}) + \frac{T_s}{2T_i} (e_n + e_{n-1}) + \Delta R_n \quad (6)$$

$$\Delta R_n = \frac{2T_d G}{2T_d + GT_s} (2I_{n-1} - I_n - I_{n-2}) + \frac{2T_d - GT_s}{2T_d + GT_s} \Delta R_{n-1} \quad (7)$$

Equation (6) is the algorithm used in the DDC programme.

where equation (7) defines  $\Delta R_n$ .

.3 CONTROL ALGORITHM (CONT'D)

For each loop the operator may specify a dead band such that if the error is within that dead band,  $e_n$  will be made equal to zero and  $I_n$  will be made equal to SP. This is done to avoid unnecessary starter motor operator, etc.

It is possible for the values of  $K_p$ ,  $T_s$ ,  $T_i$  and the resolution of the manipulated variable to be such that a large steady state error results. To avoid this problem,  $\Delta M_n$  is accumulated if it is too small to cause a change in the manipulated variables and if the error is larger than the dead band. When  $\Delta M_n$  becomes large enough to be effective, it is sent to the output.

The operator may specify a maximum incremental correction. If  $\Delta M_n$  exceeds this amount, the excess is added to the  $\Delta M_n$  computed one control interval later. If the maximum incremental correction is not specified, the "natural limit" determined by the scanning interval and the clock frequency is used.

In the case of cascaded loops, the operator can specify high and low set point limits on the level 1 controller.

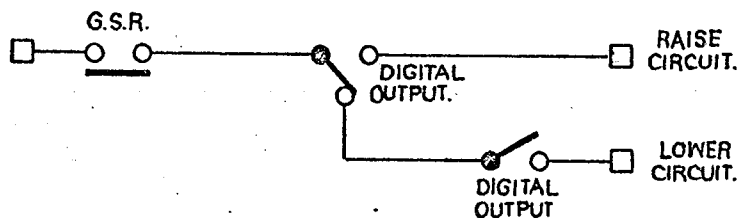
.4 CONTROL OUTPUTS

Associated with each DDC loop is a pair of digital outputs; one of which, if set, will cause the end element to move in the raise direction and the other, which, if set, would cause the end element to move in the lower direction. The programme which actually performs the outputting is initiated by a clock interrupt routine every 1/60 of a second. Depending on the sign of the calculated correction, either the raise or the lower digital output bit associated with the appropriate end element is set for a length of time equal to an integral multiple of 1/60 second interval and proportional to the magnitude of the calculated correction.

#### 6.4 CONTROL OUTPUTS (CONT'D)

In series with the two digital outputs is a group selection relay (G.S.R.) contact as shown below. The G.S.R. contact will open if the following conditions occur:

1. The Dead Man Timer times out.
2. The Emergency Disable pushbutton on the turbine run-up control panel is pushed.
3. The device being controlled is selected to manual control.

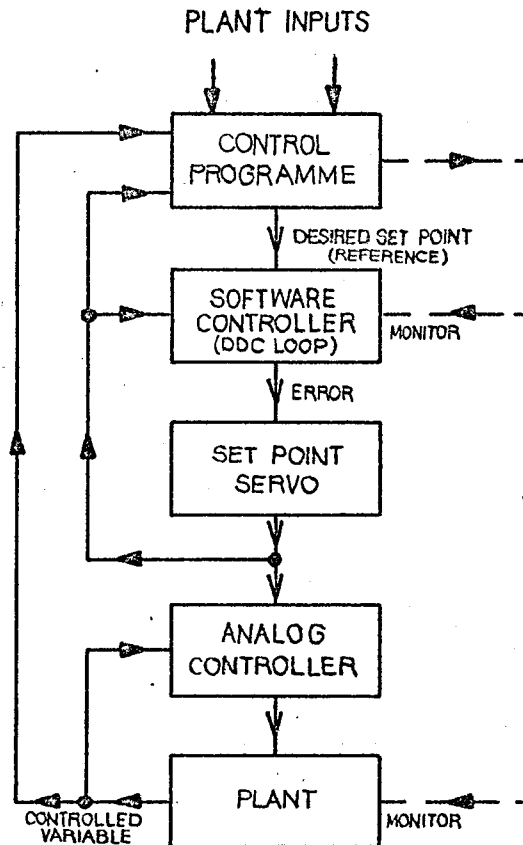


#### 6.5 DIRECT DIGITAL CONTROL OF SET POINTS (CASCADED CONTROL)

The basic programme structure followed for direct digital control (DDC) of set points of the boiler analogue control subsystem is shown in the following diagram:

The control programme logic calculates the desired setpoint as a function of the monitored plant conditions and the desired set point change; then passes that value to the DDC loop. The DDC loop then handles the first level control (regulating the Servo position) through gain, reset and rate action. The second level of control is handled through the analogue control equipment.

## 6.5 DIRECT DIGITAL CONTROL OF SETPOINTS (CONT'D)



The control programme also monitors the correspondence between:

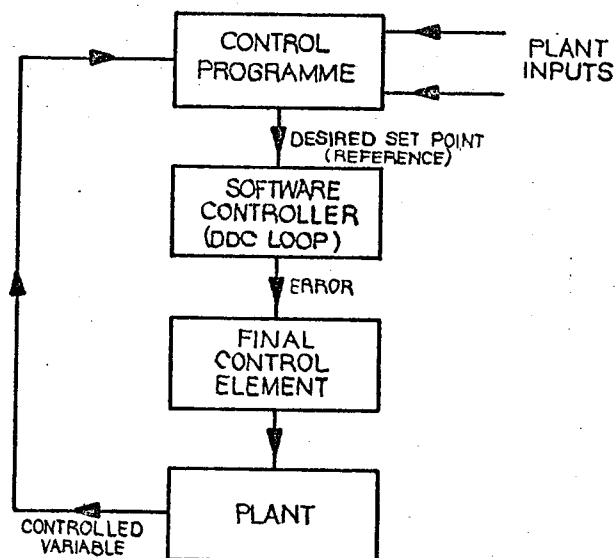
1. the desired set point and the servo output to detect any possible failures in the DDC loop or the servo.
2. the servo output and the actual value of the controlled variable to detect any failures in the analogue control equipment.

The advantage of having the computer acting on the set point via DDC rather than directly is that step changes in the desired set point will be smoothed out by the DDC program preventing "bumps" in the actual controlled variable.

## 6.6 DIRECT DIGITAL CONTROL OF FINAL CONTROL ELEMENT (NON-CASCADED CONTROL)

The basic programme structure followed for direct digital control (DDC) of final control element is shown in the following diagram.

The control programme logic calculates the desired set point as a function of the monitored plant conditions and the desired set point change; then passes that value to the DDC loop. The output of the DDC loop generates "raise" or "lower" commands to the final control element (e.g. G.O.P.C. control valve actuator or the Speeder Gear Motor).



The control programme also monitors critical plant parameters and also the deviation between the desired value (reference) and actual value of the controlled variable. Appropriate action is taken if the deviation is excessive or if one of the plant parameters exceeds a defined limit.

6.7 DDC PROGRAMMES

The Direct Digital Control Subsystem is composed of three programme modules (refer to page 93A ) as follows:

1. DDCTERM: This programme contains the controller algorithm and the controller parameters. The parameters include such information as controlled variable name and value, set point, dead bands, proportional gain constants, reset constants, sampling period, maximum and minimum value of set points and various other controller parameters. The output of this programme is a list of the desired changes in end element position (in the form of a word of COUNTS as a negative number of 1/60 second intervals).
2. DDCOUT: This programme is called by the 60 cycle clock interrupt routine and examines each word COUNT in the output list (one word COUNT per controller). If the COUNT for a controller is zero, the next controller is examined. If the COUNT is non zero, the raise or lower digital output is closed (according to the sign of the incremental correction) and the word COUNT is incremented. When the word COUNT reaches zero the appropriate digital output is opened.

6.7 DDC PROGRAMMES (CONT'D)

3. DDCS: This programme provides the panel interface for changing and reporting a particular controller parameters.

The flow diagram on page 93A shows in a general way the software interconnections and the data flow for the Liddell control function.

Six software controllers (i.e. six controller parameter tables or stacks feeding a single controller algorithm) are provided.

The DDC permissive, composed of the controlled variable selected to computer control contact ANDed with the unique auto/manual bit is computed by a calculation programme every 6 seconds; and the result stored in the system digital data field. The control programmes have immediate access to this field.

The unique auto/manual bit is set/reset by the control programmes.

The set point for the particular controller is sprayed from the control programme to the DDCTERM stack via a waiting list at the frequency of the control programme.

Analogue and other calculated data such as the actual value of the controlled variable is also placed in the particular controller stack via the waiting list.



## 6.7 DDC PROGRAMMES (CONT'D)

The programme DDCTERM is executed every 2 seconds and computes the error between desired set point and the controlled variable. The error developed is massaged by the controller velocity algorithm (refer to section 10.3) and outputs an incremental output change ( $\Delta$ ) to programme DDCOUT. Programme DDCOUT acts on the  $\Delta$  until its value is diminished, namely the particular digital output remains maintained ON until the pulse has depleted.

Appendix L shows the DDC controller manipulation in flow diagram form.

## 6.8 DDC PARAMETERS - INITIAL SETTINGS

The following table gives the initial values of some of the parameters related to each controller.

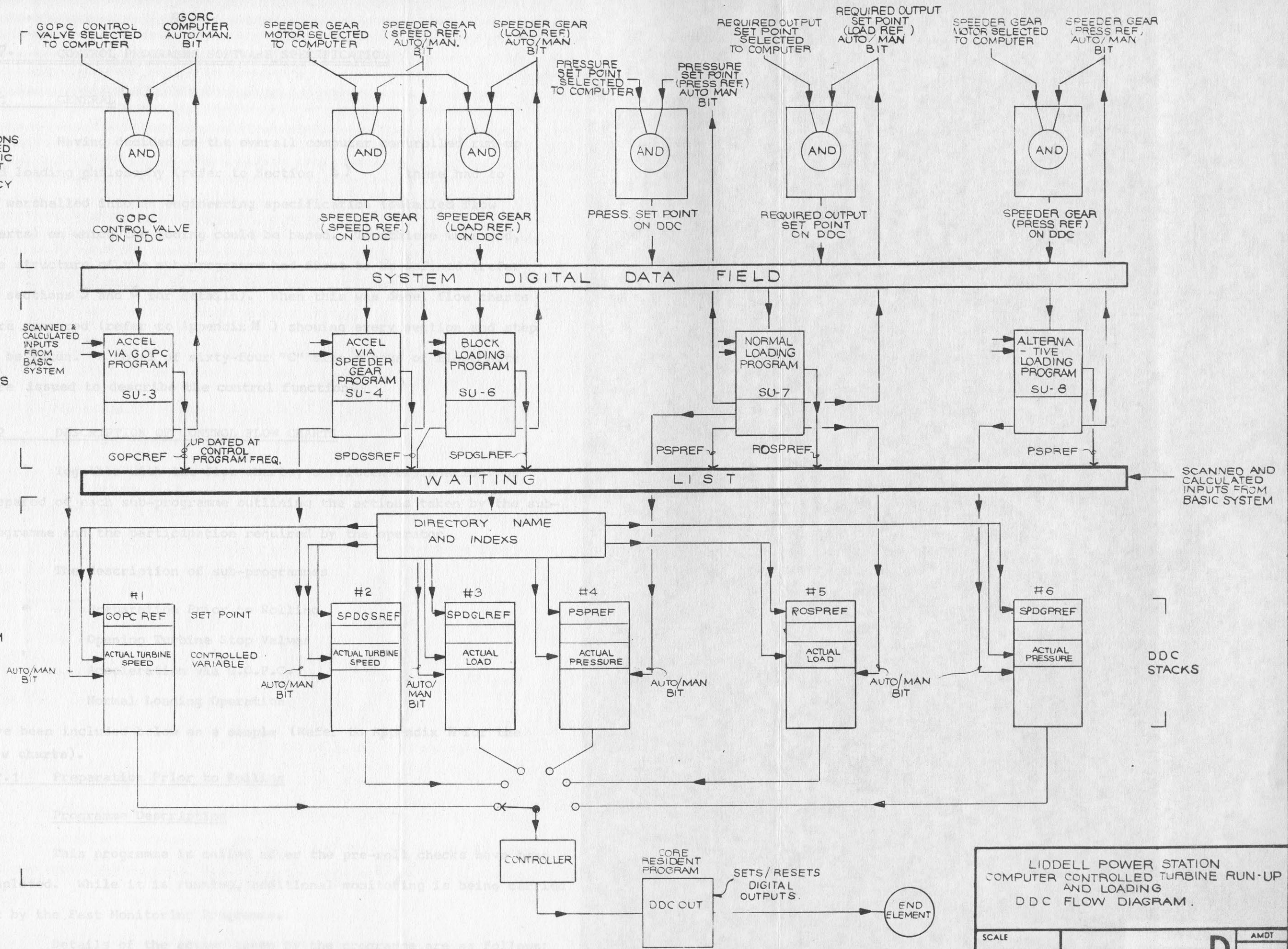
	GOPCREF	SPDGSREF	SPDGLREF	SPDGPREF	ROSPREF	PSPREF
SAMPLING PERIOD (how often the controlling variable is calculated and sprayed to the DDC programme).	2 sec.	2 sec.	6 sec.	6 sec.	6 sec.	6 sec.
Max. rate of increase of set point in set point engineering units/min.	660RPM MIN	600RPM MIN	500MW MIN	25PSI MIN	50MW MIN	25PSI MIN
Proportional gain.	0.5	0.5	0.5	0.5	0.5	0.5
Reciprocal of reset time, in repeats/min.	0.2	0.2	0.2	0.2	0.2	0.2
Rate gain, dimensionless	10	10	10	10	10	10

DIGITAL CALCULATIONS PERFORMED IN THE BASIC SYSTEM AT 6 SEC FREQUENCY

CONTROL PROGRAMS

DDCTERM

AMENDMENTS



LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE RUN-UP  
AND LOADING  
DDC FLOW DIAGRAM.

SCALE		AMD
		D

## 7. CONTROL PROGRAMME SOFTWARE SPECIFICATION

### 7.1 GENERAL

Having decided on the overall computer controlled run-up and loading philosophy (refer to Section 4) these had to be marshalled into an engineering specification (detailed flow charts) on which the coding could be based. To achieve this end, the structure of the sub-programmes had first to be defined (refer to sections 5 and 6 for details). When this was done, flow charts were prepared (refer to Appendix M) showing every section and step to be taken. A total of sixty-four "C" size sheets of flowcharts were issued to describe the control function.

### 7.2 DESCRIPTION OF CONTROL FLOW CHARTS

Together with the flow charts, a written explanation was prepared of each sub-programme outlining the actions taken by the sub-programme and the participation required by the operator.

The description of sub-programmes

Preparation Prior to Rolling

Opening Turbine Stop Valves

Acceleration via G.O.P.C.

Normal Loading Operation

have been included below as a sample (Refer to Appendix M for the flow charts).

#### 7.2.1 Preparation Prior to Rolling

##### Programme Description

This programme is called after the pre-roll checks have been completed. While it is running, additional monitoring is being carried out by the Fast Monitoring Programme.

Details of the action taken by the programme are as follows:

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.1 Preparation Prior to Rolling (Cont\*)

1. All Direct Digital Control loops are switched to manual.
2. Checks that the G.O.P.C. isolating and control valves are set to computer. If not a programme hold is initiated to allow the operator to take action.
3. Runs the speeder gear motor to minimum position.
4. Opens the G.O.P.C. motorised isolating valve.
5. Opens the G.O.P.C. modulating control valve.
6. Runs the speeder gear motor up from the minimum speed to 2940 r.p.m. position determined by a limit switch.

The G.O.P.C. control and isolating valves must be opened before running the speeder gear to the 2940 position otherwise the throttle valve would open.

A message is produced telling the operator that the computer has run speeder gear to 2940 r.p.m. position. The programme then calls the next programme "Opening Turbine Stop Valves".

#### Operator Participation

The operator will be required to switch speeder gear and G.O.P.C. isolating and control valves to computer control. If this is not done appropriate messages will be produced.

If the equipment functions correctly, no further operator participation is required.

Messages will be produced on equipment malfunctions and the operator may either correct the equipment manually or override questions for which the computer has insufficient data (because of faulty inputs).

Operation of equipment by the computer will be halted if the "HOLD" push button on the turbine run-up control panel is pressed,

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.1 Preparation Prior to Rolling (Cont'd)

however, monitoring of turbine speed will continue and tripping may be automatically initiated.

When the "RESUME" push button is pressed the programme will continue normally.

### 7.2.2 Opening Turbine Stop Valves

#### Programme Description

This programme is called after the preparations prior to rolling have been completed. While it is running, additional monitoring is being carried out by the Fast Monitoring Programme. Details of the actions taken by the programme are as follows:

1. Before proceeding with the opening of the turbine stop valves the following checks are made:
  - a) inputs used by the programme have been moved to the higher scan frequency
  - b) the H.P. valve chest steam to metal temperature differential is less than 100°F. This is to provide protection against proceeding with the opening of the turbine stop valves if the steam temperature has fallen since the last check at the prestart monitoring stage.
  - c) turbine throttle valves closed. This is to prevent inadvertent uncontrolled acceleration to take place when the stop valves are initially opened. Throttle valve closure is tested by checking the throttle valves position transmitter and governed oil pressure.
2. The stop valves are then opened slowly for the first thirty seconds before opening at a fast rate. If during the

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.2 Opening Turbine Stop Valves (Cont'd)

opening of the stop valves the acceleration or speed exceeds a certain maximum or the rate of change or pressure downstream of the throttle valve is excessive, the throttle valves are considered not closed and the turbine is tripped.

3. On completion of the opening operation an appropriate message is produced, the "READY TO RUN-UP" progress monitoring light is switched on and the acceleration via the G.O.P.C. programme is initiated.

#### Operator Participation

The operator will be required to switch the turbine stop valves to computer control. If not done, a message is produced.

If equipment functions correctly, no further operator participation is required.

Messages will be produced on equipment malfunctions and the operator may either correct the equipment manually or override questions for which the computer has insufficient data (because of faulty inputs).

Valve openings will be halted if the "HOLD" push button is pressed. However, monitoring of critical items will continue and tripping may be automatically initiated.

When the "RESUME" push button is pressed, valve opening will continue.

### 7.2.3 Acceleration via G.O.P.C.

#### Programme Description

This programme is called after the turbine stop valves have



## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.3 Acceleration via G.O.P.C. (Cont'd)

been opened. Details of actions taken by this programme are as follows:

1. Holds up progress until all inputs used in this programme are at the control frequency.
2. Starts the abnormality monitor programme.
3. Determines the acceleration and loading rates for a hot start, warm start or cold start (based on H.P. and I.P. inner casing metal temperatures and H.P. pedestal expansion.
4. DDC control of the G.O.P.C. is then set to auto. It should be noted that this programme calculates the reference speed for the DDC programme, which runs as a separate entity.
5. During the running of the programme, checks are made on critical parameters and also deviation between reference and actual turbine speed and the appropriate actions are taken, including tripping the turbine.
6. Certain checks and actions are carried out in specific speed range as follows:
 

0-300 r.p.m. (Barring Gear Range)	- Checks on barring gear operation. If checks are satisfactory, reference speed is increased at the normal rate.
900-1200 r.p.m. and 2100-2800 r.p.m. (Critical speed range)	- Computer accelerates the turbine at double normal rate. If a hold is requested in the lower half of the critical speed band, the computer reduces turbine speed at double rate until it is clear of the critical band before initiating the hold.

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.3 Acceleration via G.O.P.C. (Cont'd)

2000 r.p.m.                      - Computer initiates temperature  
(Temperature soaking      soaking by oscillating speed about  
range)                              a fixed value.

Above 2900 r.p.m.      - Computer checks operation of  
governor.

7. The reference speed is also affected by the abnormality monitor calling for a hold or run-down.

If a hold type action is called (either by the abnormality monitor or by the operator) turbine speed is oscillated 30 r.p.m. about a fixed value.

8. When turbine speed is increased sufficiently (normally to 2940 r.p.m.) the governor should prevent further speed increase. The G.O.P.C. reference speed is increased further and the DDC should close the G.O.P.C. control valve. At this stage an appropriate message is produced and the acceleration via speeder gear programme is initiated.

9. During a cold start provision is made to overcome the effect of steam being used to heat up turbine metal, rather than do useful work. When speed is less than 300 r.p.m., the acceleration rate is set to half the normal rate and the increase integral action of the DDC loop is inhibited. (i.e. action to close G.O.P.C. control valve).

#### Operator Participation

The operator will be required to switch the following items to computer control if not already done so:

G.O.P.C. Control Valve

G.O.P.C. Isolating Valve



## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.3 Acceleration via G.O.P.C. (Cont'd)

If the equipment functions correctly no further operator participation is required.

Messages will be produced on equipment malfunctions and the operator may either correct the equipment manually or override questions for which the computer has insufficient data (due to faulty inputs).

Speed increase will be halted if the "HOLD" push button is pressed (the speed being oscillated with an amplitude of 30 r.p.m. and a frequency of 30 seconds).

However, monitoring of critical items will continue and tripping may be automatically initiated.

When the "RESUME" push button is pressed, turbine acceleration will continue.

### 7.2.4 Normal Loading Programme

#### Programme Description

This programme is called after the Block Load has been applied and controls loading via DDC action on the boiler required output set point and the boiler pressure set point (refer appendix B)

Details of the action taken by the programme are as follows:

1. The values of critical inputs are continuously monitored.

If any of these values are unknown a computer HOLD is initiated and the operator is given the option to select the alternative loading programme or to recall this programme. Similar action is also taken if:

- a) the boiler analogue control equipment is not in the start-up mode and on auto (the operator was requested to take this action during the block loading period).

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.4 Normal Loading Programme (Cont'd)

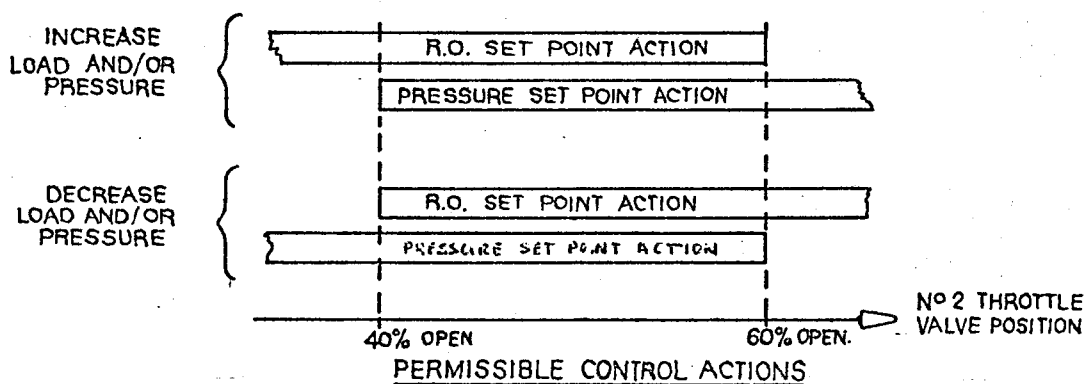
- b) Required output and pressure set point DDC loops are not on auto.
2. Providing a hold action is not required and the above checks are satisfied, the operator is request to press the "START LOADING" push button. If the button is not pressed within 15 minutes a hold is initiated as per item 1 above.
  3. Rundown action is inhibited if the "START LOADING" push button is not pressed. This is to prevent Block Loading being reduced.
  4. After the "START LOADING" push button is pressed a loading time is calculated which is used to limit the time this programme can run. This time is recalculated after every change in the target load and pressure.
  5. Operational limits due to silica and/or mills and feed pumps in service are continuously checked. Appropriate actions are taken and messages produced (e.g. "load increasing, please increase number of feed pumps in service" or "silica high, pressure increase blocked", etc.).
  6. Checks are carried out and actions taken to ensure that DDC loops are kept in alignment with the capability of the analogue control system.

If the co-ordinated analogue control equipment system is limiting required output, (e.g. due to fan loss, etc.), the required output reference is reduced to match the boiler capacity.

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.4 Normal Loading Programme (Cont'd)

7. Before loading above 300 MW is permitted, boiler pressure must be over 600 psi.
8. For cold and warm starts, loading above 300 MW is inhibited if steam temperature before turbine stop valves is less than 950°F.
9. Above 300 MW the required output reference is incremented at an increased rate.
10. Depending upon the actions called for, the limitations imposed and the No. 2 throttle valve position the computer modifies the pressure references and/or required output reference (refer to figure below).
11. When target load and pressure have been reached or loading time has expired, the programme is terminated and programme ENDALL is initiated to shut down all computer control.



#### Operator Participation

The operator must check that co-ordinated analogue control equipment required output set point and pressure set point are selected to computer control.

Large degree of operators participation is required during the loading phase to bring mills and/or feed pumps in and out of service as

## 7.2 DESCRIPTION OF CONTROL FLOW CHARTS (CONT'D)

### 7.2.4 Normal Loading Programme (Cont'd)

dictated by the load and requested by the computer.

If the pre-requisites necessary before control action can take place have not been satisfied, a computer hold is initiated and the operator is given the option to select the alternative loading programme by overriding STEP 973 and pressing the "RESUME" push button.

If STEP 973 is not overridden and the "RESUME" push button is pressed, the normal loading programme will continue.

When requested to do so by the computer, the operator is required to press the "START LOADING" push button.

Messages will be produced if the computer detects faulty inputs or incorrect equipment operation. In these cases the operator may correct the equipment or use the override facility.

At any time, target load or pressure may be changed via the man computer communications panel.

The operator may extend the loading time in increments of approximately 30 minutes by changing the target load or pressure by a small value.

## 8. TURBINE RUN-UP CONTROL PANEL

### 8.1. GENERAL

The operating personnel in the power station communicates with the computer system during the control function via a specially designed panel.

The drawing on page 110A shows the layout of the control panel. The push buttons on the panel, give overall control of the sequence while the display lamps advise the operator of the progress, completion or interruption of the sequence. The control panel is located on the Unit Control Board in the Plant Control Room.

The control programme was designed to accept instructions from and giving indication back to this control panel.

Except for the lights associated with the operation of the automatic synchronising equipment all monitoring lights are controlled by digital outputs under programme control.

To permit rapid response to the control panel all push buttons are arranged to initiate a computer priority interrupt which in turn calls the appropriate panel response programme. (refer to Appendix E for the panel response programme flow charts). Panel response programmes generally check the validity of the request and initiate any appropriate action required.

The system design is such that if any push button is pressed that button will be illuminated for approximately one second and then extinguished.

If the request cannot be granted (because of faulty inputs, equipment not selected to computer control, etc.) the light will remain on and a message will be produced indicating

## 8.1 GENERAL (CONT'D)

remain on and a message will be produced indicating the cause of the trouble. If the operator has not corrected the problem within approximately 5 minutes, a message will be produced and the light extinguished. The operator may then repress the button after the fault has been corrected. During the time that a push button light is on (awaiting the granting of a request) the operator can press other push buttons (i.e. "COMPUTER RESET" or "HOLD") and these requests will be honoured.

If two buttons are pressed concurrently, the programme logic will cause all push button lights to be illuminated for one second and an error message produced. However if one of the buttons was either "COMPUTER RESET" or computer "START-UP", the reset or start-up will be honoured, with reset taking priority.

## 8.2 PUSH BUTTON LOGIC

### 8.2.1 Computer "START-UP" Push Button

The purpose of this button is to check if the computer system is OK to control plant. When the button is pressed a programme is called which checks whether the computer power supplies are healthy, the "EMERGENCY DISABLE" push button has not been pressed, before opening all control output relays. The computer then closes the "computer control permissive" relays (refer to the drawing in Appendix showing the control hardware protection details). A message telling the operator that computer is now ready to control plant (i.e. start-up is granted) will then be produced. To protect against the generation of false control commands two digital outputs (in series) have to be closed by the computer before start-up is granted.

### 8.2.2 "START RUN UP" Push Button

The purpose of this button is to initiate computer controlled run-up if certain conditions are satisfied. When the button is pressed a programme is called which checks if boiler pressure is satisfactory (within the range 420 to 2000 psig) for the run-up operation, initiates changes in scan frequency of control input before closing the turbine control permissive relay (refer to the drawing in Appendix K ). The computer then checks if the turbine is under computer control (i.e. the G.O.P.C. control valve is selected to the computer; G.O.P.C. isolate valve is selected to computer; G.O.P.C. isolate valve is selected to computer; speeder gear selected to computer) and the turbine stop valves are under computer control.

If the above conditions are satisfied, the computer has control of the following items of plant and run-up is initiated:

1. Governor speeder gear motor
2. Turbine trip gear (oil)
3. Turbine trip gear (electrical)
4. G.O.P.C. control valve
5. Turbine stop valves.

If the operator presses the "START RUN-UP" push button before pressing the computer "START-UP" push button (or before computer start-up has been granted) a panel error message will be produced and the run-up will not be initiated.

### 8.2.3 "START SYNCHRONISER" Push Button

This button should not be pressed until the operator has been requested to do so by the computer. When the button has been pressed the hardware automatic synchroniser is brought into operation and the unit synchronised.

## 8.2      PUSH BUTTON OPERATION (CONT'D)

### 8.2.4    "STOP SYNCHRONISER" Push Button

If the hardware synchroniser fails to synchronise the unit within 5 minutes, the operator will be requested to press this button.

This button should not be pressed until the operator has been requested to do so by the computer. When the button is pressed a programme is called which closes the unit loading permissive relay (refer to the drawing in Appendix K showing the control hardware protection details) which enables the computer to have control over the following items:

1. Governor speeder gear motor (if selected to computer control).
2. Turbine trip gear (oil)
3. Turbine trip gear (electrical)
4. Required Output Setpoint of the unit co-ordinated analogue control equipment
5. Steam Pressure Setpoint of the unit co-ordinated analogue control equipment.

When control over the above items has been obtained, loading is commenced.

### 8.2.6    "HOLD" and "RESUME" Push Button

The intent of this push button is to allow the operator to call for a HOLD at any phase of the control action being performed by the computer. The computer will not immediately initiate a HOLD if plant conditions are unfavourable, but will continue control until conditions are favourable before initiating the hold (refer to section 5.5 for a more detailed description). To clear the HOLD the operator presses the "RESUME" push button.



## 8.2 PUSH BUTTON OPERATION (CONT'D)

### 8.2.7 Manual Override Push Button

The manual override push buttons may be used to answer questions that the computer is unable to answer because of faulty inputs or to permit the operator to make a decision on the action required in certain alarm conditions.

The operator should use these push buttons in response to a computer message containing details of: the question or problem, the step number (i.e. the flow chart box number) (also displayed on a digital display) for overriding and the time allowed for the operator to take overriding action. The operator may dial the step number on the digit thumb wheel and press either the YES or NO override push button.

If the operator does not override within the specified time the computer will continue controlling the plant in the safest manner possible with the information available.

### 8.2.8 Computer "RESET" Push Button

Pressing this button terminates computer control (by opening the computer control permissive digital outputs) and then initialises the system for the next run-up operation by opening the remaining digital outputs and returning all control inputs to normal scan frequencies. All progress monitoring and push button lights are extinguished and a message is produced telling the operator the speed and load at which computer control has ended. Control can only be recommenced by pressing the computer "START UP" push button.

### 8.2.9 Computer "EMERGENCY DISABLE" Push Button

This button is used to stop computer control in emergency (or after normal method has failed). The push button physically

### 8.2.9 Computer "EMERGENCY DISABLE" Push Button

disconnects the computer output relays from the plant equipment circuits (refer to drawing in Appendix K showing the control hardware protection details).

When the computer control is disconnected via this push button, the button is illuminated. When control is not disconnected, the light under the push button is extinguished.

If the push button is pressed while the computer is in control all progress monitoring lights and push button lights (except the "EMERGENCY DISABLE" push button) are extinguished and a message "control terminating - emergency disable push button pressed" is produced.

### 8.3. CONTROL STATIONS

For direct digital control applications, overriding manual control of the process end elements from the plant control room is required. This provides the operator with control when the system is off-line for any reason or when a process upset has occurred which the control programme cannot handle.

Hence for the Liddell control function, six control stations were required as follows:

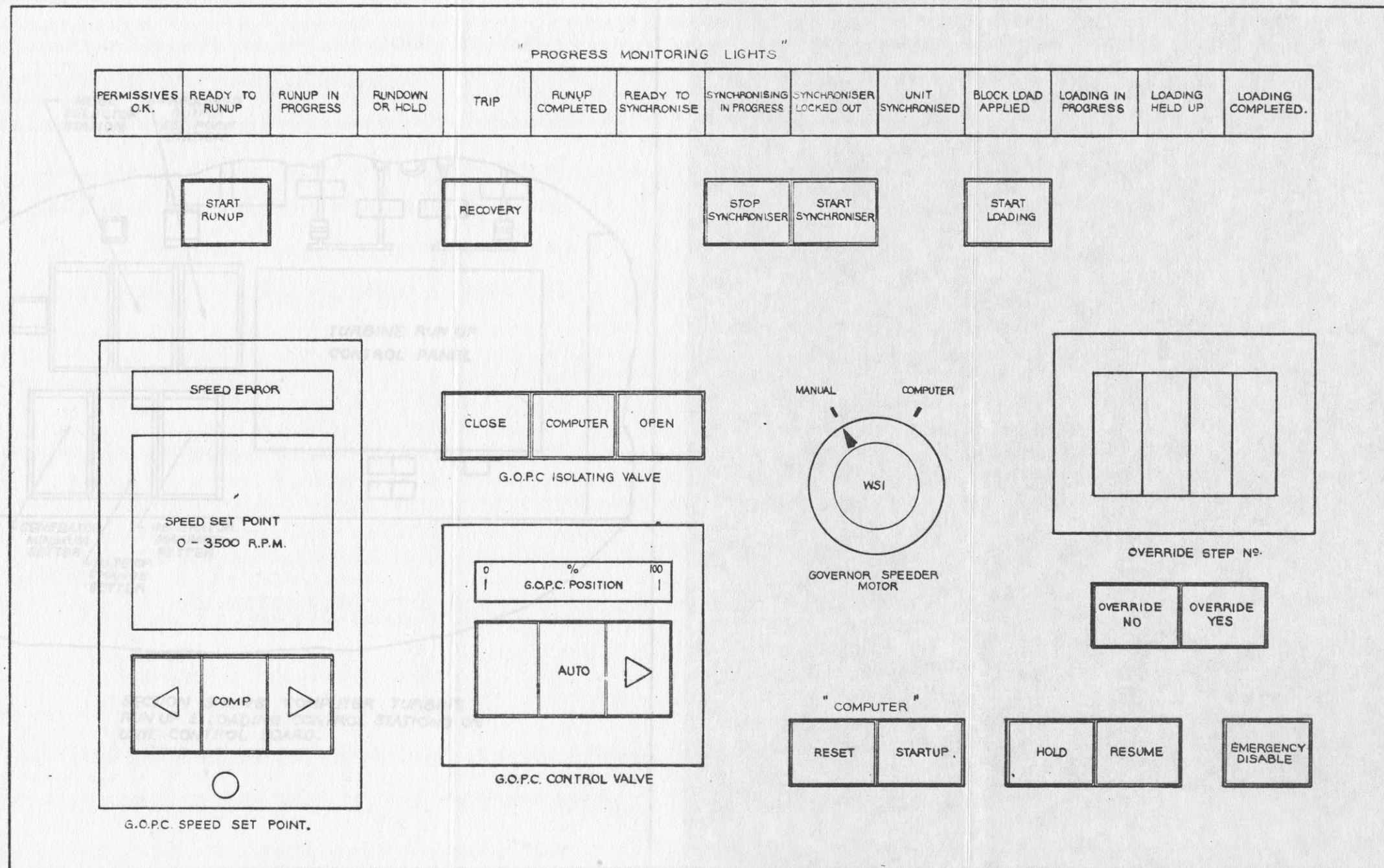
1. G.O.P.C. isolating valve
2. G.O.P.C. control valve
3. Speed Set Point Servo
4. Governor Speeder Gear Motor
5. Throttle Pressure Set Point Servo
6. Required Output Set Point Servo

8.3 CONTROL STATIONS (CONT'D)

The first four control stations are located on the turbine run-up control panel (refer to page 110A). The remaining two control stations form part of the boiler analog control equipment and are located on the Unit Control Board near the control panel (refer to page 110B).

The control stations have the following general characteristics:

- a) Manual/Computer Selection - A latching push button that enables the station to be placed under local control (Manual or analogue) or under computer control.
- b) Manual Raise/Lower - A pair of push buttons that enable the operator to manually position the end-element. When operated, they automatically disengage computer control on the channel.



## LEGEND

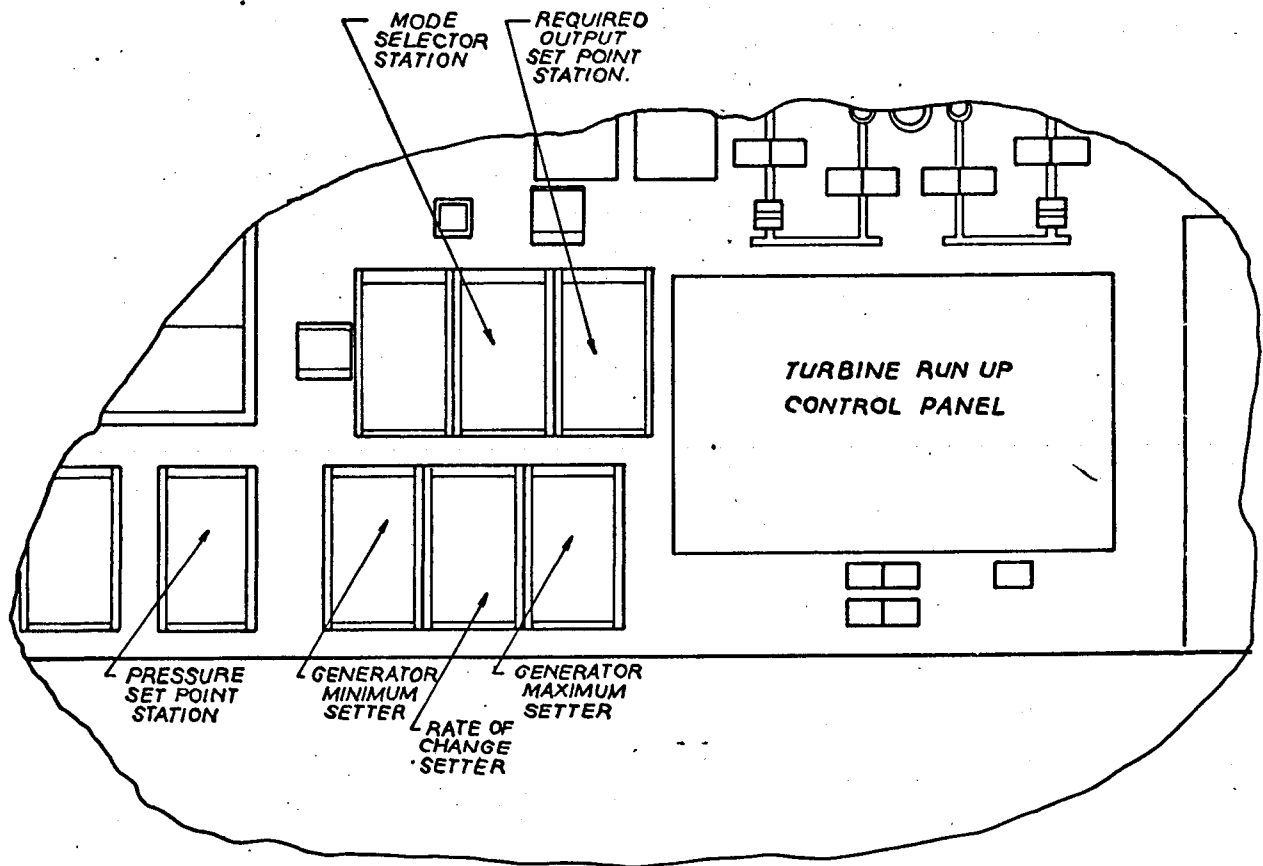
LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE RUN-UP & LOADING  
CONTROL PANEL



ILLUMINATED PUSHBUTTON.



PROGRESS MONITORING LIGHT.



SECTION SHOWS COMPUTER TURBINE  
RUN UP & LOADING CONTROL STATIONS ON  
UNIT CONTROL BOARD.

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				DATE		<div style="border: 1px solid black; padding: 2px;">E</div> <div style="border: 1px solid black; padding: 2px;">AMDT.</div>

## 9. POWER PLANT SIMULATOR

### 9.1 INTRODUCTION

The Commission decided that a power plant simulator should be developed for the following reasons:

- (i) to check out the control programmes to ensure that the programmes work correctly when applied to the turbine plant at Liddell.
- (ii) to minimise the number of power plant start-ups required to commission the control programmes;
- (iii) to provide a debugging tool so that any future control programme changes/additions can be more easily checked out and confidently placed into operation.

### 9.2 TYPE OF POWER PLANT SIMULATOR

There are two types of power plant simulators as follows:

- (a) A hardware plant simulator external to the computer system.
- (b) A software plant simulator internal to the computer system.

The hardware simulator can only be available when the main plant is shut down and considerable effort (several days) is generally necessary to change from simulation to real plant operation.

The software simulator can be available at any time (i.e. with main plant and computer system performing their normal functions) and hence has advantage in the field situation when the inevitable programme changes are required.

## 9.2 TYPE OF POWER PLANT SIMULATOR (CONT'D)

It was considered that, for the degree of automation required by the Commission, and due to the unavoidable uncertainties in main plant performance, the only real hope of achieving a satisfactory operating solution in reasonable time lay in the inclusion of a software simulator in the Liddell Computer System.

As Ebasco Services Incorporated had already developed logic for a software simulator which simulated some of the main plant dynamics, they were employed to implement this function.

## 9.3 DESIRED SIMULATOR CHARACTERISTICS FOR A SUCCESSFUL COMPUTER CONTROL APPLICATION

- (i) Simulation must be sufficient so that a minimum of actual, plant, trial startups are required.
- (ii) Must provide somewhat realistic timing and control of contact signals going to computer from equipment which control program is affecting. Must not be dependent on simulator operator to move switches in realistic time as results of control program actions.
- (iii) Must provide reasonable approximation to changes in analog inputs as a result of control program actions.
- (iv) Must provide ability to break signals whatever may real inputs can fail or make plant equipment inoperative (stuck) and see the effect on control.
- (v) Should provide relative ease of switching between real plant inputs and simulated inputs. This applied both to the TRU inputs and computer system software.
- (vi) When simulating, should not affect real plant monitoring or else must be able to assign the plant computer fully to simulator duties when needed.

9.3 DESIRED SIMULATOR CHARACTERISTICS FOR A SUCCESSFUL  
COMPUTER CONTROL APPLICATION (CONT'D)

- (vii) Should permit human to follow both control and simulator actions as easily as is practical.
- (viii) Should permit introductory training and refreshing of operators with the use of the control system without requiring plant outage or taking computer off of real plant monitoring.
- (ix) Should be modifiable to reflect developing plant characteristics and expandable to permit checkout of new or revised control program.

9.4 ON-LINE SOFTWARE SIMULATOR

The simulator sub-system consists of software models (developed by Ebasco Services Incorporated, New York) of the power plant equipment which must respond to either a relay closure or to a manual operation required to permit a dynamic real time, on-line exercise of the proposed automatic turbine run up and loading logic. Refer to page 126 for a list of software models developed.

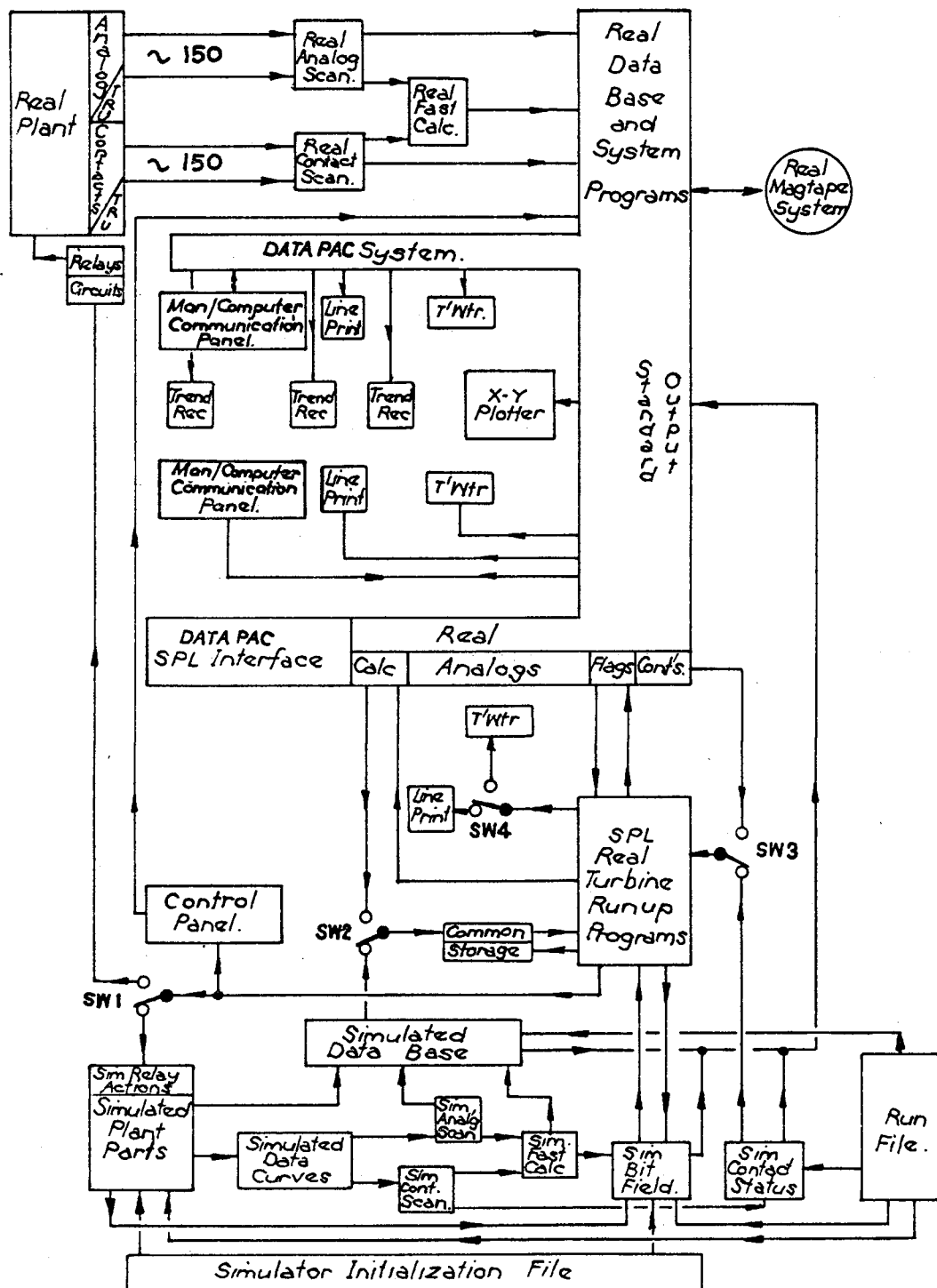


The software simulator was designed to operate in conjunction with the basic Liddell software system. (Called DATAPAC) All functions available in the basic Liddell software system continue to be available when the simulation system is active.

The drawing on page 115 shows a schematic of the Liddell system and simulator, on which is shown, in simplified form, the various connections between the simulator and the Liddell basic system (Called DATAPAC) and control programmes.

Four software switches are shown in the position indicating the redirecting of information transfer which occurs when in the simulation mode. Switch number 1 causes requests for relay actions from the turbine run-up control programmes to be sent to the simulated plant equipment programmes rather than the actual output relays. Those relay actions directly actuating lights on the Control Panel however will not be switched. Switch number 2 will cause the "COMMON" from which the control programmes are getting their analogue and calculated data to be fed from simulated data base rather than the real system. Switch number 3 enables the turbine run-up control programmes to get the simulated contact information rather than the real contact status. Switch number 4 will cause control messages to be outputted on a line printer rather than the typewriter.

The simulator initialization file enables the simulator operator to select the starting case he desires such as hot start, cold start, etc. and will cause the simulator models to be initiated in an orderly manner prior to the start of a simulated startup.



DRAWN

CHECKED

LIDDELL POWER STATION  
BASIC SYSTEM/CONTROL/SIMULATOR  
INTERFACE  
BLOCK DIAGRAM.

SCALE

AMDT.

E

DATE

The design of the simulator is such that it will perform the specified degree of run-up and loading of the power plant with minimum human influence, or permit equivalent manual operation of the same equipment. The simulator program operates in real time; therefore, a simulated loading of the unit on a hot start will take several hours.

The simulation sub-system does not simulate the turbinerun-up control panel. The control panel is used during simulation as if the control programs were controlling the real plant.

However, the operation of equipment that is not on the control panel is simulated by operating the models through the man/computer communication panels.

Thermal transients in the simulator are approximated by simple lags. All equipment contact responses are reasonably accurate with provision for delay time on items such as pressure switches. Turbine flows, temperatures, pressures etc are not thermodynamically derived but rather empirically approximated as required.

The simulation sub-system makes the following simulated variables available to the control program.

- (a) all computer inputs directly referenced in the control flow charts;
- (b) all analog and digital computer inputs fed into the calculated control inputs (i.e. the "Believed Value" calculations).

The simulator can be used to determine what the control program will do when a piece of plant equipment does not work or respond (sticks in last position) to movement

commands. The "stuck" question on each model program provides means for the human who is using the simulator to cause the simulated power plant equipment to fail to operate.

## 9.5 SIMULATED INPUTS

### 9.5.1 General

The simulation sub-system creates two types of information. The first type of information (signal) is created for the computer control programmes to respond to. They simulate those transmitters and contacts that the computer would normally see in the power plant. In other words, they simulate the transmitters that the plant computer normally senses and reacts to. These simulated signals vary with time in a manner that approximates a realistic feedback from a live power plant. However, since they do reflect actual equipment, they have a characteristic which permits them to transmit "true information", or may also transmit false information if they are in a broken condition. Thus, this class of information created in the simulator also reflects the reality of improper plant equipment reporting.

In summary, the simulated input programme information is approximately equivalent to what the computer scans would see from a real power plant under similar circumstances.

The second category of information is developed in the equipment Model programmes. This might be thought of as the true conditions of the equipment in the plant, or equivalent to what the operator would see or conclude if he went to the actual physical equipment and was capable of observing at any instant its actual status and performance with independent

(non-computer) means. This category of information is not provided to the control programmes, but rather is restricted for us by the simulated plant so that the simulated plant responds to the true plant equipment status, not the apparent status as shown by the transmitter or contact information. This input information is also available to the testing engineer or to the operator of the simulator for his usage in creating unusual circumstances. It is also used in verifying the transmitted signals to the computer when they are not broken, and seeing that the transmitted signals do not reflect correctly the plant status when it is desired that they appear broken. Such information as this second class also permits the actual condition of equipment to be available to other simulated Models so they may correctly reflect plant status at all times.

This second category of information is also used when it is necessary to have a measurement of changing conditions in a particular piece of plant equipment in order to permit the modelling mechanism to produce other simulated signals for the computer in a realistic manner.

The scanned variables, both analogues and contacts, come from equivalent, simulated transducers and simulated contacts. The analogue signals have been divided into three main categories called Type 1 Analogue, Type 2 Analogue, and Type 3 Analogue. The difference in these categories is in the manner with which the analogue signal changes with time.

## 9.52 Simulated Analogue Inputs

Type 1 Analogue Signal is a signal that processes from its starting point to a known ending point at a constant rate, or at a constant change in rate. Thus, the best illustration of a Type 1 Analogue would be a valve stem position moved by a constant speed electric motor. If the valve was sitting at 40 percent open, and the electric motor takes 100 seconds to full stroke the valve, then if the control programme closes the Valve Increase Position Relay for 10 seconds, the Model should move the valve position from the 40 percent initial position to a 50 percent final position at the end of 10 seconds. A computer scan should pick up the fact that the valve is at 42 percent after 2 seconds, 44 percent after 4 seconds, and 50 percent after 12 seconds or any other period of time greater than 12 seconds until another contact closure period is generated by the control programme. The simulator mechanism that causes the simulated scan to generate this 1 percent per second movement of the valve position is a good example of a Type 1 scan analogue. This Type 1 mechanism is used widely on devices driven by constant speed electric motor drives, and produces a simulated system variable that is available to both the control programme and the operator. A special case of this class permits the relationship in position vs. time to be a second order curve for special cases where valve flow is required to be approximated, rather than valve position.

The Type 2 Analogue is used in the modeling process where it is necessary to create an analogue variable that has the characteristics of a simple lag with respect to some other variable. A good example would be where a change in valve position creates a flow of steam of variable temperature which, in turn, changes

the temperature of the metal downstream of the valve, or a case where a pump is started, and the bearing temperature on that pump must increase from the shutoff temperature to a final value. Depending upon the accuracy required, either the second order variation of the Type 1 equation discussed above could be used, or a full Type 2 equation could be used. The use of Type 2 has more flexibility than Type 1. It permits values to be related to each other by the lag mechanism and adjustment of the amount of lag as a function of a third variable such as steam flow. This gives a simple mechanism for heat transfer phenomena, whereby the time constant at very low flows is large and decreases as flow increases. The Type 2 lag Model also provides for an offset between the driving variable and the final state of the Model variable such as required in cases of steady state heat loss.

The Type 3 Analogue Model permits a special equation to be used where necessary, and in this case in a seventh order polynomial. This is used. This is used at this time solely to obtain a new speed curve fit resulting from changes of valve position or steam pressure for an equivalent turbine.

### 9.5.3 Simulated Contact Inputs

The contacts are handled in a manner similar to the way the computer normally handles contact scans. If the Model wants to change the state of the contact, it tells the simulated contact scan the new state it wishes the contact to assume, and if it should be assumed immediately or after a defined time increment. It also has the capability of telling the scan that the contact is broken, or has just been fixed. When the contact

is broken, the open or closed status of the contact can be set such that it appears broken open (similar to a broken wire) or broken closed (similar to a short). This facility is included to permit operating engineers to investigate the effect of these common failures on the control programmes.

Each simulated analogue and contact has its present status and how it is changing stored in "scan files". The simulated scans can then use the file to produce more or less realistic changes in the values of the analogue as sensed by the computer at the times determined by the Model programmes that set up the data in these "scan files". Once the data is set in the file, the analogue scan continues at its natural rate to send the appropriate value of the particular analogue throughout the system: If the analogue is in the period during which the stored data specified that the analogue is changing, then the scan will send out appropriately changed values at proper intervals reflecting such changing. This permits the actual plant control programmes (with no modification to them) to respond in the way that they are designed to respond, thus providing realistic check on the dynamic logic of the control programmes.

## 9.6 SIMULATED OUTPUTS

The control programme acts on the real power plant by changing the status of its control output relays. Thus, if the control programme wishes to move the speeder gear motor, it will "close" the increase or decrease relay for a specific number of seconds. For example, if it wishes to move the G.O.P.C. isolating valve from the "Valve Closed" position to



the "Valve Open" position, it will set the open relay and leave it set until such time as it senses the G.O.P.C. isolating valve has opened, or sufficient time has passed such that it must be assumed that the valve has failed to open, or has opened and the limit switch failed to report the opening.

When the simulator is being used, and the control programmes try to operate the plant control relays, the interface programmes intercept the request to set an actual plant relay, and instead of operating the output relay, saves the information as to which relay was requested to actuate and calls the appropriate software model. The model then responds to that attempted relay operation. Thus, in the simulation Mode, when the control programme requests the speeder gear increase or decrease relay to be "set" the request would be intercepted and the actual plant relays would not be actuated. Instead the simulator Model of the speeder gear motor would be called into action. It would evaluate the relay request, and the duration of the "set" and in turn, it would change the information stored in the Analogue Data File for the speeder gear position, permitting the scan to show the simulated position moving in the desired direction at an appropriate speed. In addition, the Model would set itself up so that when the speeder gear mechanics reached the analogue position at which, on the actual equipment, a contact is set to change state, then the speeder gear model programme would again be event triggered and would change the contact status to the

proper status for the new position. This is a case where a pseudo-analogue (no equivalent of speeder gear position is available in the real power plant) had to be created in order for the Model to properly change the contacts at an appropriate time. In effect, the pseudo position is not available to the operator in the normal plant without going out and looking at the valve stem.

It should be noted that in all cases, the simulator tries to reasonably reproduce power plant actions of the power plant equipment, and thus requires no changing of the actual control programmes that are in the computer. This is very important since it assures that the programmes being tested are those that would actually be used in control of the real plant, and avoids the problem encountered by special paths in the control programmes for testing. Special test paths always leave the possibility that the facilities "built-in for testing", but which are not used when the real plant is being controlled, could affect the path of control taken when on the real plant, and lead to an operating error. By avoiding this, a more reliable programme check out was obtained.

## 9.7 INITIATION OF SIMULATION SYSTEM FUNCTIONS

Simulation System functions are initiated either periodically or on an event-triggered basis.

### 9.7.1 Periodic Functions

Simulated real variable data is prepared for the turbine run-up and loading programme and the equipment Model programmes are as a function of the scan frequency or calculation

interval designated to the real variable in question. Programmes to prepare this data are executed every two seconds and run immediately after the analogue scanning and processing programmes. This scheduling procedure allows analogue and calculated data to have entered the simulation system as close as possible to the same time the real data entered the system.

Simulated boolean variable data (contact inputs and boolean variables) is prepared every second. This data is gathered immediately after the digital input scan programme has completed its operations.

#### 9.7.2 Event Triggered Functions

Equipment model programmes may be requested for execution whenever a digital input changes stage, or whenever a digital output changes state. Model programmes may also be requested for execution when the value derived for a simulated real variable crosses a preset limit or when a model designates that it should be recalled after a specific time delay.

### 9.8 SIMULATOR OPERATION

The power plant simulator can be activated from the man computer Communication Panel at any time, except if the control programme is active. When activated the simulator can be operated manually or against the control programmes. However, the simulator and control programmes are interlocked so that it is impossible to stop or cancel the simulator if the control programme is also active. The control programme must be terminated first.

The system is designed to handle four sets of simulation conditions for four distinct simulation runs (cold start, warm start, hot start, hot restart).

#### 9.9 SIMULATOR CORE REQUIREMENTS

The simulator sub-system operates is approximately 7,500 words of memory. A total of 384 words are permanently assigned in memory. The 384 words contain a linkage table that enables and disables the special logic associated with simulation. The simulator initialisation procedure loads the simulation programme into core from disc memory.

#### 9.10 SIMULATOR DISC REQUIREMENTS

The equipment model programs require 100K words of disc memory for storage.

SIMULATOR MODELS

1. Fuel and Mills
2. Boiler Manual Input
3. Pressure Set Point
4. Required Output Set Point
5. Boiler Analogue Control Mode Select
6. Turbine Trip/Reset
7. Main Turbine Stop Valves
8. Power Oil System
9. Turbine Control Oil
10. Governed Oil Pressure Controller Isolating Valve
11. Governed Oil Pressure Controller Control Valve
12. Turbine Throttle Valves
13. Speeder Gear
14. Turbine Speed
15. Barring Gear
16. Field Breaker
17. Generator Circuit Breaker
18. Boiler Feed Pumps
19. Group Selection Relays

## 10. CODING AND CONTROL PROGRAMME TESTING

### 10.1 GENERAL

Once the programme specification (control-flow charts) had been completed it was the responsibility of the Computer Contractor, Leeds and Northrup Ltd., to interpret the specification, to code it, to integrate it with the Liddell software system and to independently test the logic of the programme.

The coding, integration and programme testing phase of the project was carried out at Computer Contractor's manufacturing works in the U.S.A. and commenced in November 1970. This work was carried out on the Unit 3 and Unit 4 Liddell Computer Systems before they were air freighted to Australia.

In November 1972 all site changes to the basic system software were sent to the computer contractor so they could be added to the software system incorporating the control and simulator programmes.

All sequential and monitoring control programmes were coded in the SPL IV (refer to page 123 for details of the language) language. The only exception were areas where system interface with the basic system was difficult with SPL, making machine language sub-routines more practical. Refer to Appendix 0 for a sample of the control programme coding.

The control programme check out phase involved proving the following:

1. each sub-programme performs as outlined in the flow charts;
2. each sub-programme runs properly in the system environment;
3. communication between sub-programmes is correct;
4. dynamic response of programmes is satisfactory.

## 10.2 SPL IV PROGRAMMING LANGUAGE

The SPL IV language includes all of the capabilities of Fortran IV and in addition can: —

- (i) interact with real-time data base and;
- (ii) utilise machine language sub-routines.

The major extensions of the language beyond the requirements of Fortran IV are:

### (i) LONGER VARIABLE NAMES

Names may be up to 9 characters in length.

### (ii) LABELLED COMMON AREAS FOR TRANSMITTING REAL-TIME DATA

That is, areas in memory that are used for communication of real-time values from the basic data processing programmes to the SPL programmes and between SPL programmes.

All values in a storage area are available to an SPL programme as long as the programme refers to the label (name) of the particular common area.

### (iii) CONDITIONAL COMPILING

Enables intermediate calculations and other outputs to occur to help during debugging.

Once the programmes are debugged and additional

compilation in the normal mode will cause all the conditionally marked statements to be automatically deleted from the final programme, reducing the object programme size considerably.

(iv) SYSTEM WIDE NAMES FOR VARIABLES

The names (point identification) of all analog inputs, digital inputs, calculated values and process outputs are the same throughout the system, regardless whether the programs are written in assembly or SPL language.

10.3 SPL IV ON LINE COMPILER

The SPL IV Compiler operates in the background of the on-line real time computer system.

The system capabilities are such that it is possible to write, compile and debug programme on-line without interfering with the "foreground" application programme (i.e., scanning, alarming logging, calculations etc.). Programs being checked out in the "background" mode can readily access any of the system data available to or set up by the "foreground" application programmes. User object programmes written in SPL IV can be executed in the "foreground" mode.

The SPL IV package included the compiler, loader and run time support packages. In the event the compiler is operating and a foreground program is scheduled to run, control of the system will return to the foreground program. The minimum running



time of the compiler is 50 milliseconds before it can be pre-empted by the foreground program; this is to provide a reasonable time for the compiler to complete execution of the source statement being entered by a programmer.

When programs assigned hardware external interrupt levels request processing (i.e., sequence of events, operator panel request, power failsafe, etc.), the compiler is immediately pre emptied.

The SPL IV compiler operates is approximately 8K of core memory.

#### 10.4. ON-LINE TRACE FACILITY

Both during the simulated and real runs of the control programme it is important to know what the programmes have done so that when an error or unsuspected result is encountered, its cause can be determined, a "fix" designed, installed, checked and another run made. However, during debugging it is desirable to avoid inserting special statements in the control programmes as much as possible. This permits them to be debugged in the form they will actually run.

Hence a set of debugging aids were needed to minimise the time taken to accomplish this cycle, particularly to prevent having to repeat runs to get information not printed out the first time through. Repeat runs have other problems as well, because sometimes the problems do not appear the second time due to some differences in tuning or equipment condition on the second run.

For this reason a fairly powerful on-line trace system was required to follow all significant control programme internal and external actions. The on-line trace system must have selectable printing capability also. Yet, if unexpected actions occur, one needs to be able to stop and then decide what previously stored trace information to print out. This approach saves time and avoids preguessing where errors might occur.

The on-line trace package supplied contained a set of flag bits that permitted tracing or not tracing of each individual control sub-programme and each simulator model programme.

If a programme is traced, all significant changes are recorded on a disc file and the appropriate print matrix for that programme is checked to see if it is a change that should be also printed as detected. This option permits the engineer to follow selected items of programme as they execute but retains the balance of the amount of disc memory that can temporarily allocate for this purpose. However, the disc area did not need to be solely dedicated for this purpose. Full or selected printing can be initiated from the beginning of the file or from a specific time contained on the file when detailed information is required.

#### 10.5. CONTROL PROGRAMME MEMORY USAGE

Approximately 8K words of core memory was required to implement the control function (includes 6.5 K words of overlay area).

The SPL control programmes required 80K words of disc memory for storage. Each programme contains 5-25% spare space for future expansion.

#### 10.6 DYNAMIC TESTING OF CONTROL PROGRAMMES

The dynamic tests (or simulated closed loop tests) were based on an independent software power plant simulator developed by Ebasco Services Incorporated, New York, for the Commission (refer to section 9 for details) which allowed the control loops to be closed for the dynamic response of the programmes to be tested.

The software simulator gave quite a realistic representation of the power plant and allowed the effect on control response, of, for example, different control loop gain settings, to be studied.

#### 10.7. PROGRAMMING STATISTICS

A total of 605 man days was spent on coding, documenting and testing of the control flow charts.

## 11. PLANT AND CONTROL PROGRAMME INTEGRATION

### 11.1. GENERAL

The completion of the control programme testing phase (refer to section /0 ) meant that the control and simulator programmes were now fully integrated into a copy of the Liddell basic system software. (as of November 1972)

The new software system was sent to Liddell Power Station in January 1973.

At this stage before the control programmes could be integrated with the power plant the following steps are considered necessary:

1. Load and run the new software system in each Liddell computer system;
2. Add the Liddell site software changes from November 1972 to the new system software;
3. Verify the plant inputs on which the control programme specification is based.
4. Check the operation of the control panel and digital outputs;
5. Carry out test on the power plant to establish that the control and simulator programme specification satisfies the plant requirements;
6. Plant Test data evaluation and operating procedures review.
7. Operator familiarisation and acceptance.

The following paragraphs describe these steps in more detail.

#### 11.2. SITE CHECKOUT OF NEW SOFTWARE SYSTEM

The new software system was loaded into one of the Liddell Computer Systems and checked out to ensure all basic functions were operational.

#### 11.3. ADDITIONS OF SITE SOFTWARE CHANGES TO THE NEW SYSTEM SOFTWARE

The new system software evolved from a copy of the Liddell system software dated November 1972. By the time the new system software arrived at site a number of additional software changes had been made to Liddell software. These changes had to be integrated into the new software system.

Steps 1 and 2 have been completed successfully.

The following steps are expected to be completed by early 1975.

#### 11.4. FUNCTION CHECKOUT OF ALL CONTROL INPUTS

This means that all plant inputs on which the control programme specification is based should be verified as far as possible. Assuming that the calculation programmes used by the control function have been tested and verified to be correct any deviation detected in the result will probably be caused by incorrect wiring, improper setting of a contact, or by incorrect calibration of an analogue, or combination of these faults. Each contact must be operated individually to prove proper wiring to the computer. The correct dynamic operation of each contact must also be verified. A contact from a relay must be proved by operation of the circuit containing the relay. This type of test

is the only way to ensure the information intended to be provided by the relay is correct. Contacts representing position of devices such as valves must be proven correct by operating the device.

In every case where a contact or several contacts make up a calculation, the value output as determined by the calculation must also be proven correct.

The analogue inputs require calibration in addition to correct wiring verification.

#### 11.5. CONTROL PANEL WIRING CHECKOUT

The reason for this step is to prove the control panel operates correctly and that the computer output relays operate on the correct piece of plant equipment under computer control. The unit of necessity must be out of service during this period.

The schematic shown in Appendix K is a part of the control wiring that has to be checked out. The actual operation of each of the Group Selection Relays (GSRI through GSR6) must be observed to operate in response to computer relays in accordance with the logic represented on the wiring diagram. The contact inputs emanating from the GSR's must also be verified as various GSR's are operated.

#### 11.6. PLANT TESTS

The aim of this step is to collect data for the purpose of updating the modelling programmes of the simulator and control programmes. The series of tests required are as follows:

(i) Phase 1 Static Test (Unit off line turbine at rest)

Continuous Full Stroke Test for the Following Equipment:

1. GOPC isolating valve
2. GOPC control valve
3. Speeder Gear
4. Stop valves at slow speed
5. Stop valves at fast speed
6. Throttle valves
7. Steam pressure set point
8. Required output set point

The valves are to be stroked to determine precisely as possible the length of time for all full travel through the 0 to 100% open range. Particular attention is to be given to dead time at beginning of an opening cycle and over travel (if any) at the end of the opening cycle. Both opening and closing cycles are to be repeated enough times to ensure sufficient data to determine, repeatability and hysteresis characteristics for calibration purposes.

Series Pulse/Pause Full Stroke Test on Following Equipment:

1. GOPC control valve
2. Throttle Valve
3. Steam Pressure set point
4. Required output set point

This phase of valve tests involves moving the valve through its range via a series of fixed small pulses, with a pause between pulses. A special programme is to be written which will generate the pulses and the pauses (3 or 4 seconds) starting when the valve is closed and ending when the valve is fully open. The

process will then be reversed to close the valve.

Random Pulse/Pause Test on same Equipment as above Test:

The next test requires that the valve firstly be positioned by hand as accurately as possible to a fixed position of 25% open. The pulse and pauses between each pulse should then be applied via the computer as follows:

3 open pulse, 1 closing pulse, 2 opening pulses, 1 closing pulse, 3 open, 2 close, 1 open, 3 close, 1 open, 3 close. The valve position is expected be back at 25% after such a series of random motions, however, its actual travel and final position will reveal significant data on the behaviour of the valve. The series of pulses described and the valve starting position can be arbitrary. From these results, a decision about the need of collecting more data or varying the pattern, etc. can be made.

The full stroke series pulse test and the random pulse test just described must also be applied at various pulse lengths.

It is proposed that the first size of pulse will be 3 seconds. Tests will also be made at 2 seconds, 1½ seconds, 1 second, ¾ of a second, and ½ of a second.

An attempt will be made first to find the smallest size pulse that produces motion of the valve. The tests at ½ second will probably dicte what other small pulse sizes, whether measured in seconds or cycles, should be investigated.



The procedure described above will be accomplished via programme which will control the equipment and collect the data, perform the various accounting jobs (calculating differences in position movement, etc.) and then outputting the information.

(ii) Phase 2 Test Turbine Dynamic Characteristic Test (Unit off line, Boiler at a "Typical" Steady State Steam Condition, Turbine Rolling)

The next series of tests involve operating the turbine via the governed oil pressure controller (GOPC) control valve at various speeds to determine the dynamic characteristics of the turbine. Tests are to be performed under cold start and warm start conditions which are anticipated as representing the averaging starting boiler and turbine conditions. The speed governor setting must be at maximum position to prevent it taking over at higher speeds.

The tests are to be performed ,by first hand adjusting the turbine to some minimum speed plateau, say about 500 rpm and allowing it to settle to a steady state speed for at least 15 to 30 minutes.

The next operation is to make a precise step change in valve position, using the computer, and allowing speed to settle at some new plateau. The settling time could run as long as half an hour.

The size of a step change planned is one which produces a speed change of at least 500 rpm, but not more than 1000 rpm.

Assuming selection of a pulse length will produce a 500 rpm change, the tests would cover a series of plateaus which would be 500, 1000, 1500, and 2000, 2500 and 3000 rpm.

The plateaus do not have to be exact. The pulse applied at each step can be different as long as its value is known. There should be at least five plateaus reached, none of which occur at near a critical speed of the turbine.

Steam conditions are to be held as constant as possible during the speed tests. The result of these tests will enable verification of mathematical models of the turbine and its control logic.

With the turbine rolling at approximately 3000rpm, the speeder gear mechanism is to be lowered manually to its minimum position and the speed allowed to settle.

Fixed pulses are to be sent to the speeder gear via the computer to raise the speed in a series of steps to some reasonable amount of overspeed. At each step the speed will be allowed to settle before the next pulse is sent. The speed will be lowered in the same fashion.

Upon completion of the governor tests, data will then be collected on the "Takeover" control characteristics between the speeder gear and GOPC control valve. This will be tested primarily at 2940 rpm setting of the speeder gear.

The excitation tests are to be performed with the

speeder gear under governor control at several speed settings between minimum and 3070 prm. Data is to be collected on the field current and voltage and generator voltage with and without automatic voltage regulator in service. The effect on turbine speed due to applying excitation to the particular generator is to be tested also at various speeder gear settings. Of particular interest will be the possibility of control returning automatically to the GOPC control valve due to speed decrease when excitation is applied.

(iii) Phase 3 Tests

Turbine Dynamic Characteristics Test During Loading  
(Unit on-line Boiler at "Typical" Steady State  
Steam Condition)

The purpose of this series of test is to collect data to checkout the loading phase of the operation. The data collected during this test will be collected in a manner that duplicates the control programme loading phase.

11.7. PLANT TEST DATA EVALUATION AND OPERATING PROCEDURES REVIEW

After the above plant test each model in the simulator must be reviewed in terms of the actual operating characteristic of the equipment it represents. Each control programme must also be reviewed in terms of actual operating experience.

The aim of this step is to finalise the control flow charts and programmes in light of present operating procedures. Simulation testing is to be carried out to verify the programming modification.

## 118. OPERATOR FAMILIARISATION AND ACCEPTANCE

This step involves familiarising those responsible for the operation of the plant with the characteristics of the control and simulator programmes in order that their co-operation may be obtained. (Refer to Appendix S for operator training flow chart example).

After the above steps have been completed the control programmes can be commissioned as outlined below.

### 11.9 CONTROL PROGRAMME COMMISSIONING

Before commissioning the acceleration and loading programmes (DDC loops) the following programmes should be tested:

1. The control panel programmes;
2. Preparations prior to rolling programme;
3. Opening turbine stop valves programme;
4. Plant Parameter Monitoring programme.

For the above test the unit must be out of service.

The panel programmes actually call into service many other programmes and sub-routines in the process of establishing proper conditions for entry into the first major control programme.

The control termination programmes would then be tested to check their ability to initiate an actual trip of the unit. However, the trip circuit would be disarmed to prevent actual trips from occurring via the computer during programme testing phase.

The satisfactory completion of this phase of testing means that the DDC portions of the control function can be tested.

The first loop will be the acceleration via the GOPC control valve. The main task will be the tuning of the DDC parameters to achieve a smooth acceleration through the various phases of the operation.

The control programmes contain enough adaptive features to enable special tuning for any condition if required. It is entirely possible, however, that one set of tuning constants will provide satisfactory operation over the complete range of accelerating conditions. The tests will be attempted first, in the non-adaptive mode and with tuning constants found best on the simulator.

The remaining DDC loops will be commissioned in the following order:

1. Acceleration via speeder gear
2. Block loading via speeder gear
3. Normal loading via R.O. set point and pressure set point of the boiler analog control equipment
4. Alternative loading via speeder gear.

The control function is expected to be fully commissioned by early 1975.

## 12. FUTURE DIGITAL CONTROL APPLICATIONS

The following is a list of suggested improvements for future digital control applications.

### 12.1 SOFTWARE ITEMS

1. For the Liddell Control function, logic was provided to permit overriding of questions for which the computer had insufficient data i.e., unknown questions. Facilities should also be provided to permit overriding of known questions. An example of the use of this facility would be in the pre-roll checks where the plant may be in the incorrect state as far as the pre-roll checks are concerned but the operator may be happy to permit the control to continue. This is particularly important in the pre-roll check area because the combinations of plant which are permissible for various conditions of operation are very complex and would require a very extensive computer programme for full and adequate checking.
2. A large amount of unnecessary detail appeared on the flowcharts as the result of flags, counters, etc., for the production of messages. Standard logic should be produced for message production, to enable the flags and counters to be removed from the flowcharts. This approach could also be used for questions which involved counters.
3. For the Liddell control function the opening and closing of on/off type valves was done via a sub-routine. This approach has the disadvantage that, while the valve is being operated, the only logic of main programme which is capable of being used is that

preceeding the sub-routine. It is felt that a better method would be to open and close valves, etc., asynchronously to main programmes. The main programme would probably set a required status flag for each valve and a periodic valve operating programme would open or close valves as required and set appropriate actual status flags. The use of actual status flags saves duplication of "believed valve" calculations and overriding logic.

If necessary the main programme could check (via the actual status flag) to see if the valve was in the required position but would not be held up on monitoring, or other control duties while awaiting positioning of the valve.

If this approach is taken the flags for each valve, etc., must have three states:

- (a) The desired status flag must have one state for "open", one for "shut" and one for "don't care".

The "don't care" status would permit the valve to be operated on by the main programme if a special operation was required, i.e., inching open or intermediate positioning, but would still allow the valve programme to operate when the valve was only required to be open and shut. (An example of this would be the turbine stop valves);

- (b) The actual status flag must have "open", "closed" and "elsewhere" status.

Other states may be required, depending upon the logic used for unknown inputs.

4. It is suggested that a sequencing programme be used to run programmes rather than passing from one programme to another. This would permit much more flexibility for recovery after a computer stall and could also simplify turbine recovery programmes. It should also simplify programme modification.
5. It is suggested that only one progress flag be used in conjunction with the sequencing programme. An attempt should be made to use a section of the flag to indicate the sequence within an individual programme (e.g., if 7 indicated that the acceleration via speeder gear programme was running, certain stages of this programme could be indicated by setting the flag to 7.1, 7.2, 7.3, etc.) This would give more flexibility and possibly enable re-starting within sections of programmes rather than re-starting at the beginning, depending on plant conditions, etc.
6. As an extension of Item 3, an asynchronous approach to the control could be used, with the sequencer or perhaps the main running programme checking that each of the required asynchronous programme have been run. This approach would allow several operations to be done at once during an emergency operation, such as turbine recovery.



7. At Liddell, plant monitoring via control programmes was split into two major levels, abnormality type monitoring and monitoring done by sequencing programmes. It is worth investigating the extension of the abnormality type monitor to cover some of the functions normally done by sequencing programmes. For example, the abnormality monitor could check on deviations from reference and also other variables which change during the run-up sequence. These variables could be used as inputs to the abnormality monitor and the actions taken by the abnormality monitor would be reflected in all other programmes. This could result in a major simplification of sequencing type programmes, particularly ones which take similar actions but use different items of equipment, e.g., when accelerating by GOPC or speeder gear, or alternatively in the several loading programmes.

A disadvantage of extending the use of the abnormality monitor is that operators, etc., must look at two separate programmes to get a full picture of computer control at any specific section of a sequence. This must be weighed against the advantages gained. A possible solution is to show summarised abnormality monitor logic on the main programme flowcharts, preferably in tabular form.

8. The abnormality monitor logic could be vastly simplified by the use of transforms of inputs (or "believed values") to the programme. In the abnormality monitor for Liddell, counting logic is used to remove the effects of noise and ensure that action is not taken on one reading of an input. This

could quite easily be done with the smoothing or running average transforms of inputs or "believed value" calculations and removing the counting logic. This whole concept however is dependent upon the method used for calculation of "believed values".

9. Facilities should be provided to permit the operator to manually set references. With the Liddell system, references such as reference speed were set by the control programs and by these programmes only. However, in an unusual operating condition, the operator should be able to set either his reference for speed say, or alternatively, to be able to set a reference change rate so that a semi-manual control of run-up or loading could be obtained. Manual setting of a reference or reference rate should block normal changes or reference by control programmes but not block run-down or hold actions.
10. At Liddell a considerable amount of time was wasted in the re-numbering of digital output relay. It is suggested that items such as this should be cross-referenced via a table. The table would contain the computer identification number and all reference in programmes to this table should refer to the number of the item in the table. Thus any changes that occurred at a later date would only require modification of the table and not a search through the flowcharts. If this method is used, it should also be ensured that the programming is also done by means of a table search. If this is not done, the simplification of documentation modification will be far outweighed by the programme modification and checking problems introduced.

# 11. SOFTWARE ITEMS (CONT'D)

11. The Liddell control function uses a "Periodic Type" programming structure as opposed to the "Event Type" programming structure.

"Periodic Control Programmes" are defined as plant control programmes which operate on a routine basis (i.e. every 2 seconds, 6 seconds, etc.) to do a particular task (i.e. regulate a valve, monitor an aspect of operation, etc.).

"Event Type Control Programmes" are defined as programmes which are only run ("triggered") on the occurrence of one of the following specific events:

- (a) the change of state of a digital input calculation;
- (b) the exceeding of a limit by an analog input or calculation;
- (c) the change of any analog input or calculation by a predetermined amount.

Periodic control programmes are in general easier to write and easier to understand but tend to give poorer control (where excellence is required) and to demand large amounts of computer system time and other resources, and are relatively difficult to modify once at site.

Event type programmes are more difficult to write and understand but can give excellent control, demand little computing time and are easy to field modify.

In conclusion, the event type control programmes should be used for future digital control applications.

SOFTWARE ITEMS (CONT'D)

12. The present control scheme as shown on the Commissions flow charts is as follows:

- (a) Acceleration by DDC action on the G.O.P.C. control valve to 2940 r.p.m.
- (b) The changeover to computer control of the speeder gear for acceleration to 3060 r.p.m.
- (c) The changeover to the Brush Synchroniser speed control circuits for gradual coasting down in speed (via the speeder gear) and synchronising.
- (d) The changeover to computer control of the speeder gear for block load application.

In the above approach there are too many changeovers in control and a better method would have been to use the G.O.P.C. control valve during acceleration, synchronising and block loading as follows:

- (a) Acceleration to 3060 r.p.m. under computer control of G.O.P.C. control valve.
- (b) Use the Brush Synchroniser for synchronising, however the control of speed during the synchronising process should be handled by the computer which would cause the speed to oscillate slowly about 3000 rpm. Synchronising can occur on either the fall or the rise of speed.
- (c) Application of the block load while still using the computer control of the G.O.P.C. control valve.
- (d) The changeover to throttle valve position control by the speeder gear to occur after synchronising and the block load application.

2 HARDWARE ITEMS

1. On the run-up panel, at least one light should be illuminated all the time if the computer is in control of the plant. A suggested extension of this is for the progress monitoring lights to be illuminated so as to indicate in a "bar" fashion the progress within the control sequence. Thus not one light but a series of lights would be on at all times other than at the time of starting.

As an extension of the above, lights indicating holds, run-down, etc., should not be in the main line of progress lights, but should be located in a second line. These lights could also possibly be of a different colour to the main progress sequence lights.

2. The arrangement of Group Selection Relay's used at Liddell cause considerable limitation to control flexibility. It is suggested that the following points should be borne in mind when designing the hardware layout:

- (a) One GSR or its equivalent should be used for each output group but smaller grouping should be used than was used at Liddell, eg., if the turbine speed input goes bad, the computer should be able to block action on turbine speed via a GSR. Other actions however such as tripping should still be capable of being carried out under computer control;
- (b) At Liddell, if a critical item of plant is not switched to computer control, then all computer control of the turbine is lost. This is most unsatisfactory as it does not permit items of plant to be operated manually without loss of all computer control. It also necessitates a return to the start of the run-up sequence to regain control.

One example of this from Liddell is that the computer is not permitted to accelerate the turbine under GOPC control if the speeder gear is not selected to the computer.

Provision should be made for individual items of plant to be switched off computer control, the plant positioned manually and then the plant either switched back to computer or some sort of override used to indicate that the item of plant is in the correct position, while permitting computer control, monitoring, etc., to continue.

3. Provision should be made for the computer to check its own control interlocks (i.e. whether GSR's have latched, etc.) and inform the operator which GSR or which interlock is not made.

CONCLUSION

The computer control turbine run up and loading facility at Liddell power station is the Electricity Commission of N.S.W. first venture in computer control.

Because of Industrial problems and failure of plant at critical time the commissioning of the control function has been postponed a number of times. However it is hoped that by early 1975, the control function will be commissioned.

Some of the advantages of computer control are as follows:

- (a) Input transducer signals can be tested in many ways before being used to develop a control signal.
- (b) The computer being used for direct digital control is capable of diagnosing itself for the majority of its ills and can place the control loops in manual so that no faulty control action will occur.
- (c) Often we discover there are peculiarities about each process and control strategies must be changed to accommodate these peculiarities. The computer has virtually unlimited arithmetic capability. The control engineer need not worry about cost or time delays when he feels the need to add additional logic.
- (d) Because digital computer calculations are error free and drift free, direct digital control settings are exact, reproducible and non-interacting e.g., the setting of gain constant and reset rate have no affect on each other whatsoever.

The simulator proved very important in that it enables the control program to be readily and realistically demonstrated. Different start up conditions could be simulated and the run up observed the same as if it was a live run up. In this way, all the facilities of the control programme could not only be dynamically tested but also demonstrated. There is no doubt that these demonstrations will do a great deal to establish confidence in the automatic run up facility.

The digital computer holds promise of being capable of not only implementing automatic turbine run-up and loading but also to implement full automation of the power plant in the future. On this ground alone, the Commission believed it worthwhile to venture into computer control at Liddell Power Station.



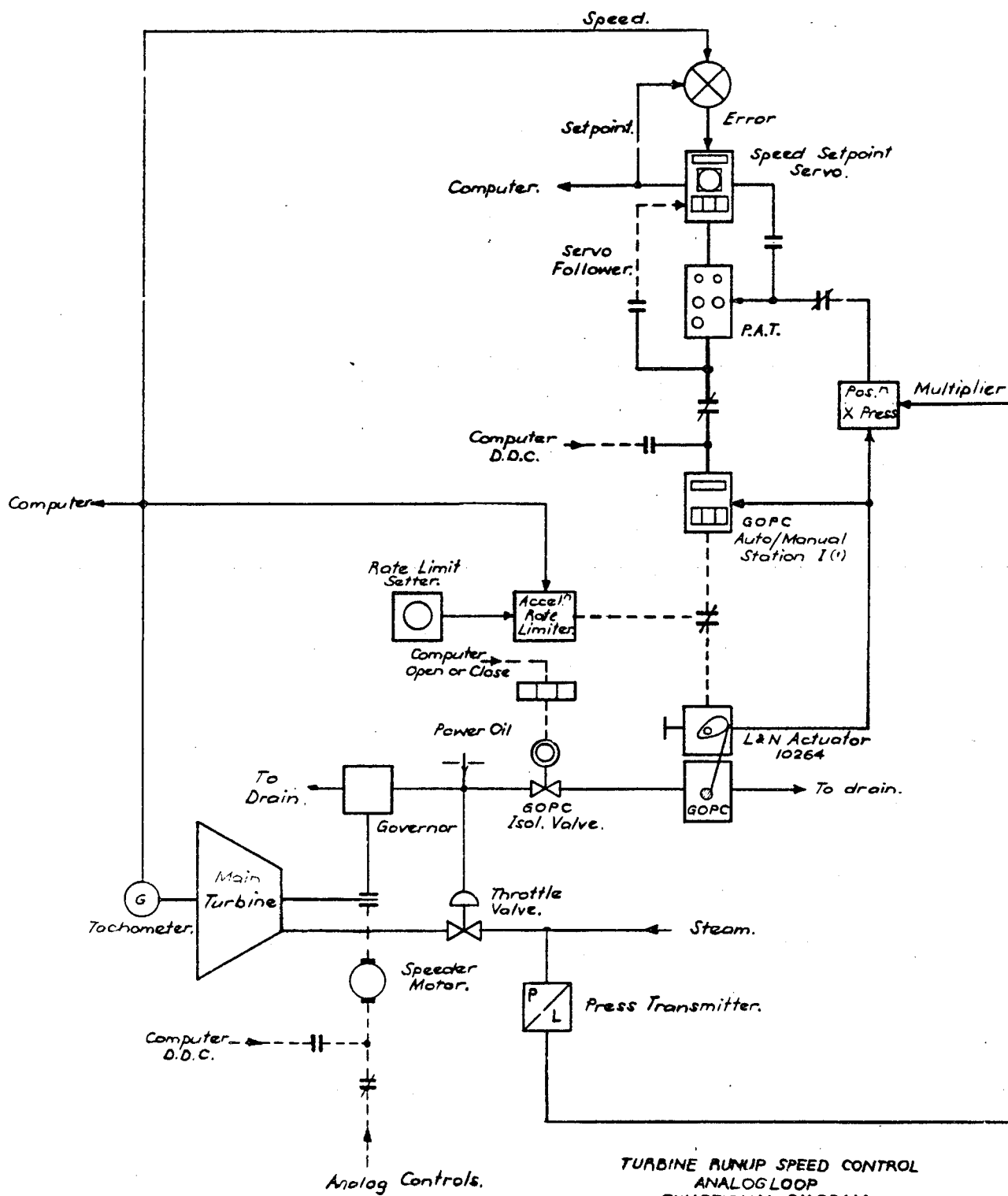
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## APPENDIX A

AUTOMATIC TURBINE RUN-UP

ANALOG SPEED CONTROL LOOP



## APPENDIX B

### UNIT CO-ORDINATED ANALOG CONTROLS

### COMPUTER CONTROL LOADING

### MODE



## APPENDIX C

### ON LINE REAL TIME COMPUTER SYSTEM

#### HARDWARE BLOCK DIAGRAM





## **APPENDIX D**

### **XDS SIGMA II GENERAL CHARACTERISTICS**

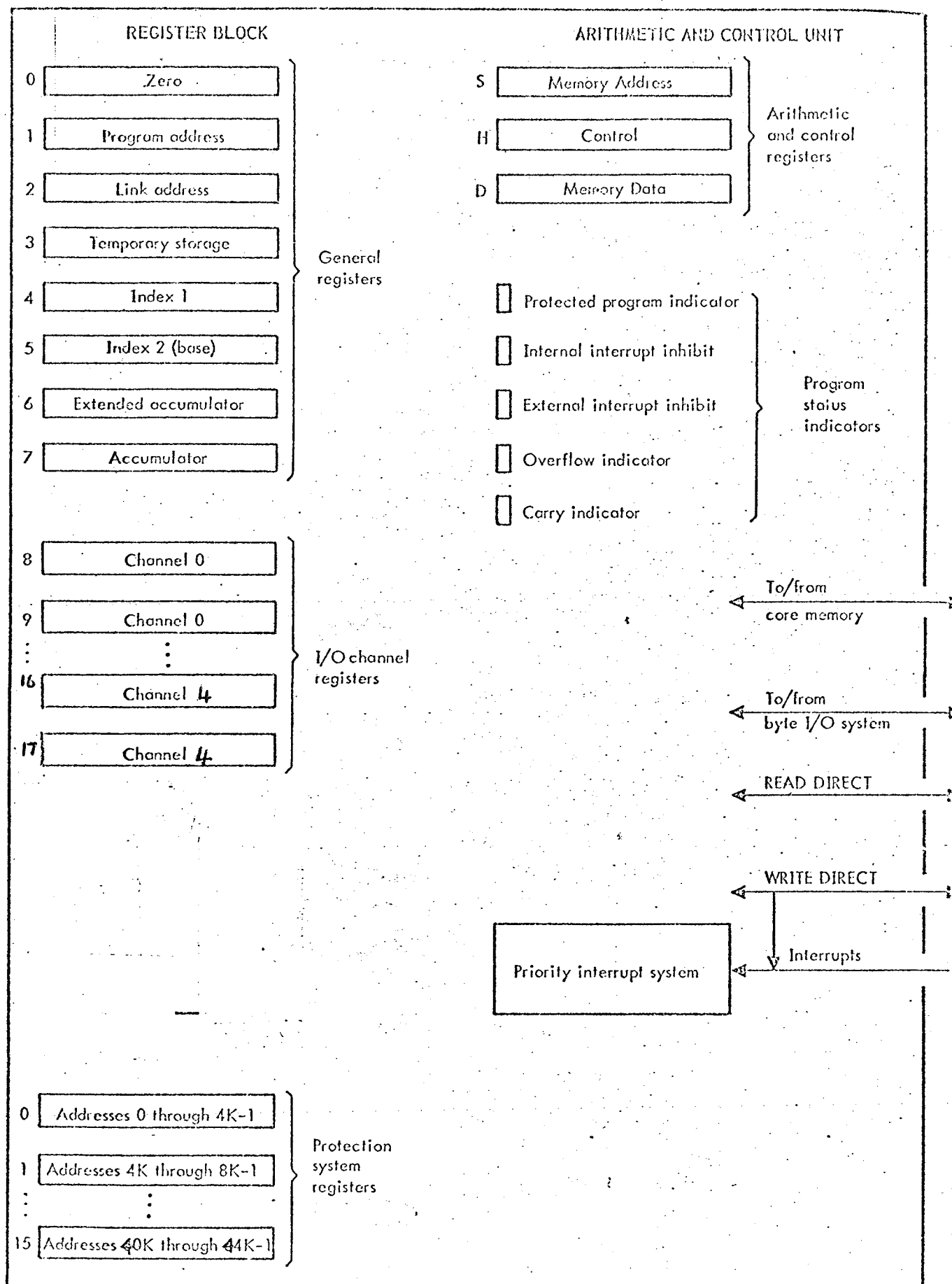


## XDS SIGMA II GENERAL CHARACTERISTICS

- 1) both word and byte organization of memory for maximum efficiency (words are 16 bits plus parity; bytes are 9 bits)
- 2) an extensive instruction set that facilitates efficient programming; Sigma II instruction characteristics include:
  - a) only one word of storage required for each instruction
  - b) two levels of indexing and indirect addressing may be invoked individually or simultaneously
  - c) relative addressing (forward and backward)
  - d) use of index register 2 as a base address register
  - e) direct reference of up to 1024 addresses; 256 addresses beginning with location zero, 256 addresses beginning with the base address; 256 addresses beginning with the current instruction location (relative forward), 256 addresses backward from the current instruction (relative backward)
- 3) eight general-purpose registers to control programme operations; all are available to the programme, providing:
  - a) two hardware index registers for preindexing (base address), post-indexing, or both (double indexing)
  - b) hardware register for subroutine linkages
  - c) double-precision accumulator
  - d) programme address register
  - e) zero register (for a source of zeros)
  - f) temporary storage register
- 4) rapid context switching, to preserve computer environment when switching from one programme to another including automatic status preservation on interrupt

XDS SIGMA II GENERAL CHARACTERISTICS (CONTD.)

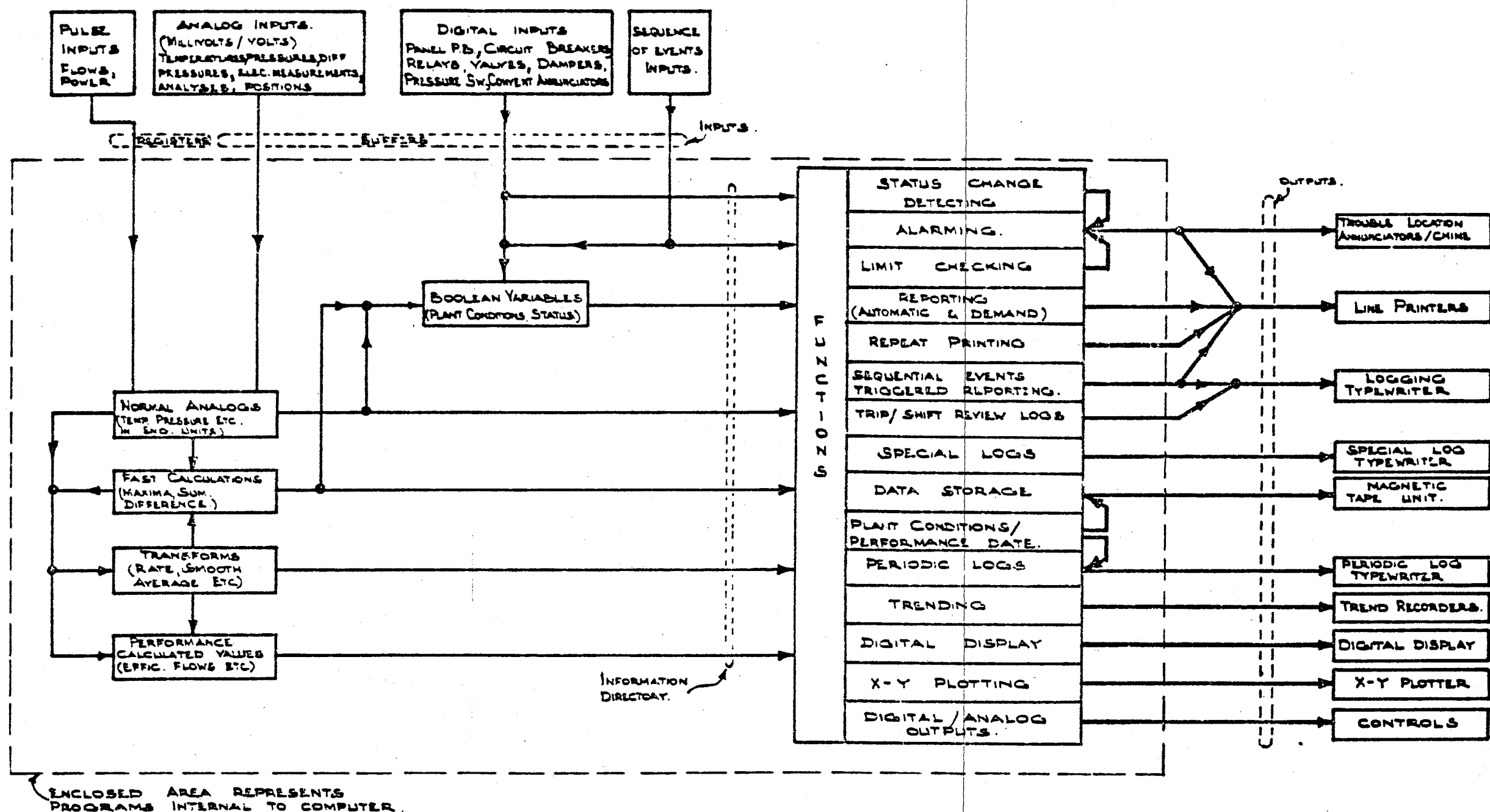
- 5) both word-and byte-oriented C.P.U. I/O systems for maximum flexibility
- 6) four fully automatic byte-oriented I/O channels operating simultaneously
- 7) direct input/output of a full word
- 8) a real-time priority interrupt system that features:
  - a) 5 internal interrupt levels and 11 external interrupt levels that can be individually armed, enabled and triggered by programme control
  - b) Memory parity interrupt
  - c) power fail-safe feature, for automatic and safe shut-down in the event of a power failure, and unattended start-up when power returns.
  - d) system protection feature that includes both memory write protection and operation protection for foreground programme
  - e) a real-time clock.



## APPENDIX E

### LIDDELL COMPUTER SYSTEM

#### FUNCTIONAL DIAGRAM



LN5200 COMPUTER SYSTEM FUNCTION DIAGRAM.

## APPENDIX F

### COMPUTER INPUT/OUTPUT HARDWARE SPECIFICATION

**TABLE 1****SPECIFICATION OF ANALOGUE INPUT SUBSYSTEM**

Specification	Multiplexer Type	
	High Level	Low Level
Input Range	0 to $\pm$ 1V dc	0 to $\pm$ 50 MV dc
Speed (points per second)	900	120
Module Size	4 inputs per card	4 inputs per card
Card File Size	48 points per card file	
Input Switching	Reed relay	Mercury-wetted relay
Accuracy (at 3 sigma limit)	0.1% F.S.	0.1% F.S.
Common Mode Noise rejection	$10^6$ :1 dc to 60 Hz (120 db)	$10^7$ :1 dc to 60Hz (140 db)
Maximum Common Mode Voltage without damage	Up to 250V dc or peak ac	Up to 500V dc or peak ac
Differential Mode Noise Rejection	400:1 at 60Hz	1000:1 at 60Hz
Maximum Differential Mode Voltage without damage	15V, peak, AC or DC	
Input Type	Two wire, differential	
Differential Filter	Single stage R-C	Two stage R-C
Source Resistance for 0.01% error	1000 $\Omega$	492 $\Omega$
Overload Recovery (Input signal from which the system will recover without affecting accuracy of next input, if immediately addressed).	$\pm$ 5 V	$\pm$ 250 MV
Standard Deviation at Reference Condition	0.123%	0.0108%
Reference Condition	Ambient Temperature: 77°F Relative Humidity : 50% Powerline Voltage : 107 to 126 volts, ac, and Frequency 50 to 60Hz	
Resolution	14 Bits, plus sign (1 part in 16,384)	

Filter time constant 160 usec.

TABLE 2

SPECIFICATION FOR DIGITAL INPUTS

<p>A. <u>DIGITAL STATUS INPUTS</u></p> <p>Scanning Speed</p> <p>Module Size</p> <p>Input Type</p> <p>Protection</p> <p>Signal Response Time</p>	<p>1200 points per second</p> <p>16 inputs per card</p> <p>Optical</p> <p>240V d.c.</p> <p>200 ms on closure; 1 ms on opening</p>
<p>B. <u>PULSE INPUTS</u></p> <p>Operating Rate</p> <p>Counter Size</p>	<p>Up to 15 pulses per second</p> <p>4 bit counter</p>
<p>C. <u>DIGITAL EVENT</u></p> <p>Sequence Resolution</p> <p>Time Resolution</p>	<p>2 ms</p> <p>4.2 ms</p>



TABLE 3

SPECIFICATION FOR ANALOGUE OUTPUTS

FULL SCALE OUTPUT SIGNAL	+ 1 to + 5 mA
INPUT DATA	10 bits plus sign
ACCURACY	$\pm 0.1\%$ OF FULL SCALE
RESOLUTION	1 part per 1024
CONVERSION TIME	200 microseconds, (0 to full scale)
LOAD	1.5 K $\Omega$ MAX

TABLE 4ANALOGUE INPUT SCALING AMPLIFIER SPECIFICATION

ITEM	SPECIFICATION
Manufacturer	Astrodata
Type	Isolated Differential
DC Gain Accuracy	$\pm 0.1\%$
Gain Stability	$\pm 0.01\%$ for 40 hours $\pm 0.05\%$ for 1,000 hours
Temperature Coefficient of Gain	$\pm 0.005\%$ per degree Fahrenheit from $35^{\circ}$ to $120^{\circ}\text{F}$
Linearity	$\pm 0.02\%$ of full scale output
Input Impedance	Greater than 100 megohms shunted by less than 500 picrofarads.
Output voltage	$\pm 10$ Volts DC or peak AC
Output Impedance	Less than 1 Ohm in series with 50 microhenries
Short Circuit Protection	Momentary or sustained output short circuits will not damage amplifier
Drift for 40 hour period	less than $\pm 1$ microvolt referred to the input and $\pm 0.005\%$ of full scale.
Noise	Less than 1 millivolt at a gain of 200
Common-Mode Rejection	Greater than 160 db at DC, 120 db at 60 Hz
Common-Mode Voltage	Up to $\pm 300$ volts DC or peak AC
Operation Ambient Temperature Range	$32^{\circ}$ to $122^{\circ}\text{F}$

TABLE 5  
ANALOGUE TO DIGITAL CONVERTER SPECIFICATION

ITEM	SPECIFICATION
Resolution	15 bits including sign
Input Voltage Range	$\pm 10$ volts full scale
Accuracy	$\pm 0.01\%$ of full scale plus $\frac{1}{2}$ least significant bit
Conversion time	180 microseconds

## APPENDIX G

### PERFORMANCE CHARACTERISTICS OF PERIPHERAL EQUIPMENT

## PERFORMANCE CHARACTERISTICS OF PERIPHERAL EQUIPMENT

### 1. DISC

Make	DIGITAL DEVELOPMENT CORPORATION
Model No.	7302
Type	Head-per-track
Average Access Time	8.5 milliseconds
Data Transfer Rate	2 megacycles/sec.
Capacity	2 megabytes
Speed	3600 r.p.m.
Tracks/surface	64

### 2. TYPEWRITERS

Make	FRIDEN FLEXOWRITER
Model	2305
Typing Speed	16 characters per second
Code	ASC II
Printable Characters	Numeric, alpha (26 symbols)
Horizontal Spacing	12 characters/inch
Vertical Spacing	6 lines/inch
Paper	Fanfold Sprocket feed
Paper width	21.5 inches
No. of Characters/line	27 <sup>4</sup>

### 3. STRIP PRINTERS

Make	Franklin Electronics
Type	drum printer
Printing Speed	20 lines per second
No. of columns	20
Vertical Spacing	6 lines/inch
Printable characters	0 to 9, upper case alphabet *, +, -, ., space
Paper	Fan-fold, roll-feed
Paper Size	2-3/4 inches wide

4.

X-Y PLOTTER

Make	Calcomp Model 565
Increment Size	0.01 inches (on both drum axis and carriage axis)
Speed of Plotting	10 operations/second (up and down pen movement)
Plotting width	11 inches
Drum axis operating Speed	300 increments/second
Carriage axis operating speed	300 increments/second
Accuracy	+ step in either axis or over entire roll of paper

5.

DIGITAL DISPLAY

Make	Indus Electronic Engineers Inc.
No. of digits	6
Size of Display	1" characters

6.

HIGH-SPEED PAPER TAPE INPUT/OUTPUT SYSTEM

Read mechanism	photoelectric
Read speed	300 characters/second
Punch speed	120 characters/second
Rewind/Fast Forward Speed	200 inches/second
Start time(reading)	less than 6 milliseconds
Stop time(reading)	within 1 millisecond
Tape Format	8 channels
Code	EBCDIC

7.

TREND-RECORDERS

Make	L & N	L & N
Model	M-Line	WL-Line
NO Pens	3 Pen	3 Pen
Chart speed	2ins/hr.	2 ins/hr, 6 ins/hr.

8.

MAGNETIC TAPE UNITS

Make	XDS
Model No.	7362
Type	Vacuum column
Tape Speed	37.5 inches per second
Start/Stop Time	10 msec.
Rewind Speed	150 inches per second
Information Transfer Rate	20,850 bytes/second
Recording Method	NRZ1 (non-return to zero, change on ones)
Recording format	7 channels
Recording Density	556 bits per inch

## APPENDIX H

### CONTROL SCAN FREQUENCY

### OF ANALOG INPUTS



CONTROL SCAN FREQUENCY

FOR ANALOG INPUTS

When no control programs are running, the analog inputs are scanned at the "normal frequency".

When the control function is initiated, a request is made to set all control inputs to the control frequency.

NORMAL AND CONTROL SCAN FREQUENCY OF ANALOG INPUTS

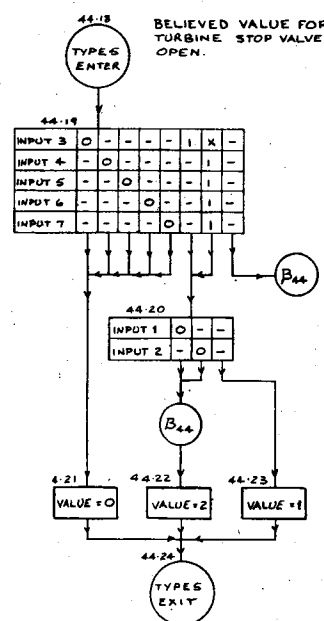
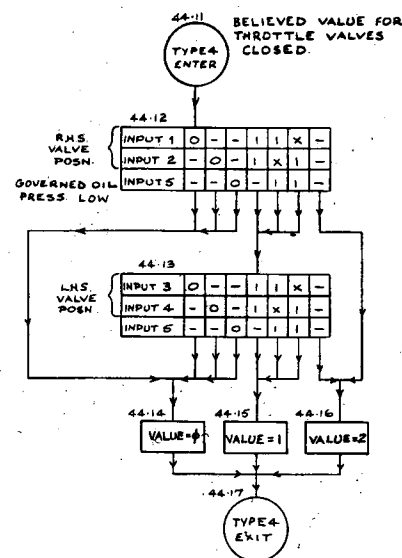
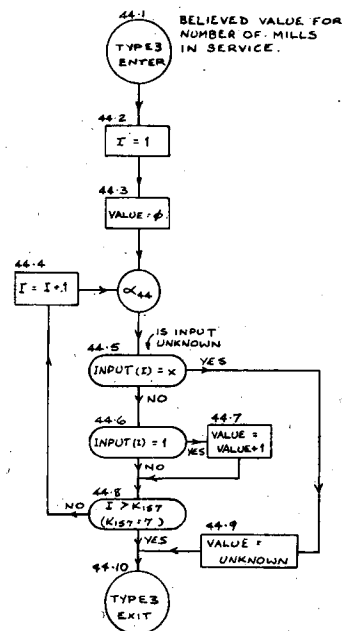
INPUT NUMBER	DESCRIPTION	NORMAL FREQUENCY (SECONDS)	CONTROL FREQUENCY (SECONDS)
A0156	MAIN STEAM LH INNER WALL MTL TEMP	30	30
A0157	MAIN STEAM LH OUTER WALL MTL TEMP	30	30
A0158	MAIN STEAM RH INNER WALL MTL TEMP	30	30
A0159	MAIN STEAM RH OUTER WALL MTL TEMP	30	30
A0160	BIFURCATION LH INNER WALL MTL TEMP	30	30
A0161	BIFURCATION LH OUTER WALL MTL TEMP	30	30
A0162	BIFURCATION RH INNER WALL MTL TEMP	30	30
A0163	BIFURCATION RH OUTER WALL MTL TEMP	30	30
A0345	SFPT POWER OIL PRESS	30	30
A0346	SFPT LUBE OIL PRESS	30	30
A0356	SFP GLAND SEAL SYST DISCH PRESS	30	30
A0357	SFPT LUBE TANK LEVEL	30	30
A0358	TURB R.P.M. - H.P. GEN	2	2
A0359	TURB R.P.M. - TACHO	2	2
A0360	TURB R.P.M. - PLS TACHO	2	2
A0361	TURB TV RH 1 POSITN	60	6
A0362	TURB TV RH 2 POSITN	6	6
A0363	TURB TV LH 1 POSITN	60	6
A0364	TURB TV LH 2 POSITN	6	6
A0402	TURB SV LH A OUTER METAL TEMP	60	12
A0403	TURB SV LH A INNER METAL TEMP	60	12
A0404	TURB SV RH B OUTER METAL TEMP	60	12
A0405	TURB SV RH B INNER METAL TEMP	60	12
A0406	TURB TV LH 1 OUTER METAL TEMP	60	12
A0407	TURB TV LH 1 INNER METAL TEMP	60	12
A0408	TURB TV RH 1 OUTER METAL TEMP	60	12
A0409	TURB TV RH 1 INNER METAL TEMP	60	12
A0418	HP INNER STUB 1 OUTER METAL TEMP	60	12
A0419	HP INNER STUB 1 MID METAL TEMP	60	12
A0420	HP INNER STUB 1 INNR METAL TEMP	60	12
A0421	HP INNER STUB 2 OUTER METAL TEMP	60	12
A0422	HP INNER STUB 2 MID METAL TEMP	60	12

NORMAL AND CONTROL SCAN FREQUENCY OF ANALOG INPUTS (CONTINUED)

INPUT NUMBER	DESCRIPTION	NORMAL FREQUENCY (SECONDS)	CONTROL FREQUENCY (SECONDS)
A0423	HP INNER STUB 2 INNER METAL TEMP	60	12
A0424	HP INNER FLNGE INNER WALL MTL TEMP	60	12
A0425	HP INNER FLNGE QUATR SP CNG MTL TEMP	60	12
A0426	HP INNER FLNGE OUTER WALL MTL TEMP	60	12
A0429	HP OFLNGE INL RH MID METAL TEMP	30	30
A0431	HP OFLNGE INL LH MID METAL TEMP	30	30
A0439	HP O.CASE INLET 1 MID METAL TEMP	60	12
A0440	HP O.CASE REV 2 INNR METAL TEMP	30	30
A0441	HP O.CASE REV 2 MID METAL TEMP	60	12
A0442	HP O.CASE INLET 2 MID METAL TEMP	30	30
A0443	HP O.CASE REV 3 MID METAL TEMP	60	12
A0445	HP O.CASE REV 4 MID METAL TEMP	60	12
A0455	IP INNER STUB 1 OUTR METAL TEMP	60	12
A0456	IP INNER STUB 1 INNR METAL TEMP	60	12
A0457	IP INNER STUB 2 OUTR METAL TEMP	60	12
A0458	IP INNER STUB 2 INNR METAL TEMP	60	12
A0464	IP OFLNGE INL RH MID METAL TEMP	30	30
A0466	IP OFLNGE INL LH MID METAL TEMP	30	30
A0467	IP OUTER INLET 1 MID METAL TEMP	60	12
A0468	IP OUTER INLET 2 MID METAL TEMP	60	12
A0469	IP OUTER INLET 3 MID METAL TEMP	60	12
A0470	IP OUTER INLET 4 MID METAL TEMP	60	12
A0479	TURB HP ECCENTRICITY	30	6
A0480	TURB IP ECCENTRICITY	30	6
A0482	TURB HP PEDESTL EXPN	60	12
A0483	TURB HP DIFF EXPANSN	60	12
A0484	TURB IP DIFF EXPANSN	60	12
A0485	TURB LP DIFF EXPANSN	60	12
A0487	TURB BRG 2 HP VIBRN	60	12
A0488	TURB BRG 3 IP VIBRN	60	12
A0489	TURB BRG 4 IP VIBRN	60	12
A0490	TURB BRG 5 LP 1 VIBRN	60	12

## APPENDIX I

### EXAMPLES OF BELIEVED VALVE LOGIC



# NOTES:

## TYPE3

### FOR INPUTS

1 = ON (IN SERVICE)  
0 = OFF (OUT OF SERVICE)  
X = UNKNOWN

## TYPE4

### FOR INPUTS 1-4 (ANALOG)

X = UNKNOWN  
1 =  $\leq K185$  (K185 = 2.5%)  
0 =  $> K185$   
- = ANY CONDITION

### FOR INPUT 5

X = UNKNOWN  
1 = TRUE  
0 = FALSE  
- = ANY CONDITION

### FOR VALUE

0 = FALSE  
1 = TRUE  
2 = UNKNOWN

## TYPE5

### FOR INPUTS 1-2

1 =  $> K184$  (K184 = 200 PSI)  
0 =  $\leq K184$   
X = UNKNOWN  
- = ANY CONDITION

### FOR INPUTS 3-7

1 = TRUE  
0 = FALSE  
X = UNKNOWN  
- = ANY CONDITION

### FOR VALUE

0 = FALSE  
1 = TRUE  
2 = UNKNOWN

## FLAG TABLE

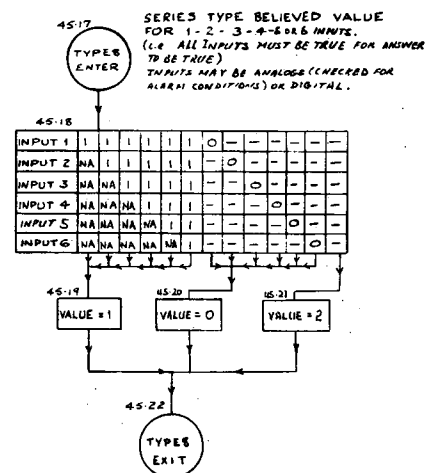
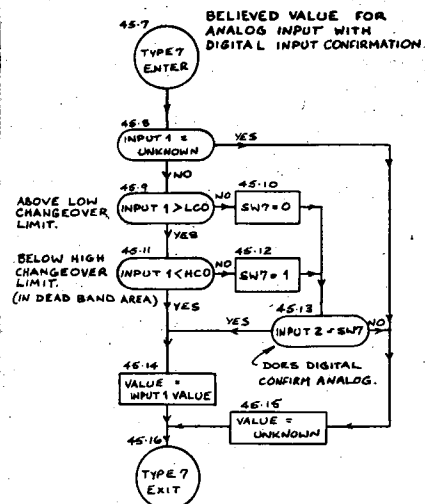
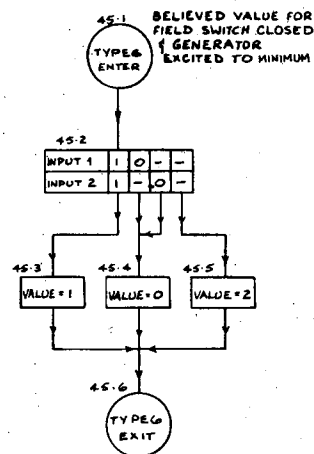
NAME	DESCRIPTION	EXTERNAL FLAGS ONLY	
		SET BY PROGRAM	RESET BY PROGRAM
I	INDEX FOR INPUTS		
VALUE	VALUE OF B.V.		
INPUT#N	VALUE OF EACH INPUT (REFER DATA TABLE)		

AMENDMENTS  
REVISION FROM  
PROGRAMMING  
DATE N.S. 10/10/69  
A.S.E. 10/10/69

## THE ELECTRICITY COMMISSION OF N.S.W.

LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 44  
BELIEVED VALUE ROUTINES

SCALE	DATE	DATE
DRAWN DBL		10/10/69
TRACED		G.A. Glesson
CHECKED JC		EIED
DATE 10/10/69	LD267254 CII	



## NOTES

### TYPE 6

#### FOR INPUT 1

1 = K<sub>166</sub> (K<sub>166</sub> = 1.660)  
 0 = > K<sub>166</sub>  
 X = UNKNOWN  
 - = ANY CONDITION

#### FOR INPUT 2

1 = TRUE  
 0 = FALSE  
 X = UNKNOWN  
 - = ANY STATE

#### FOR VALUE

0 = FALSE  
 1 = TRUE  
 2 = UNKNOWN

### TYPE 7

#### FOR INPUT 1

0 = BELOW SETTING  
 1 = ABOVE SETTING  
 X = UNKNOWN

### TYPE 8

#### FOR DIGITAL INPUTS

0 = FALSE  
 1 = TRUE  
 X = UNKNOWN  
 NA = NO INPUT ALLOCATED  
 - = ANY STATE

#### FOR ANALOG VALUES

1 = OK (NOT IN ALARM) [QUALITY = 0]  
 0 = IN ALARM [QUALITY 1 OR 2]  
 X = QUALITY > 2  
 NA = NO INPUT ALLOCATED  
 - = ANY STATE

#### FOR VALUE

0 = FALSE  
 1 = TRUE  
 2 = UNKNOWN

NAME	DESCRIPTION	EXTERNAL FLAGS ONLY
INPUT 1	VALUE OF EACH INPUT (REFER DATA TABLES)	SET BY PROGRAM
VALUE	VALUE OF B.V.	RESET BY PROGRAM
SW7	SWITCH FOR REV TYPE 7	

LAST BOX NO. 45.22

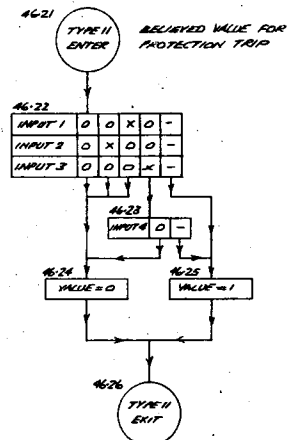
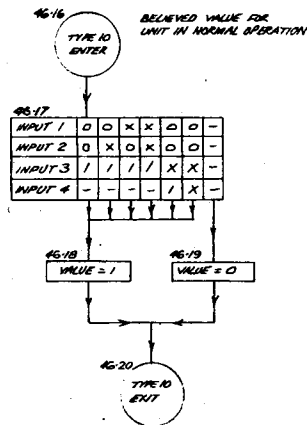
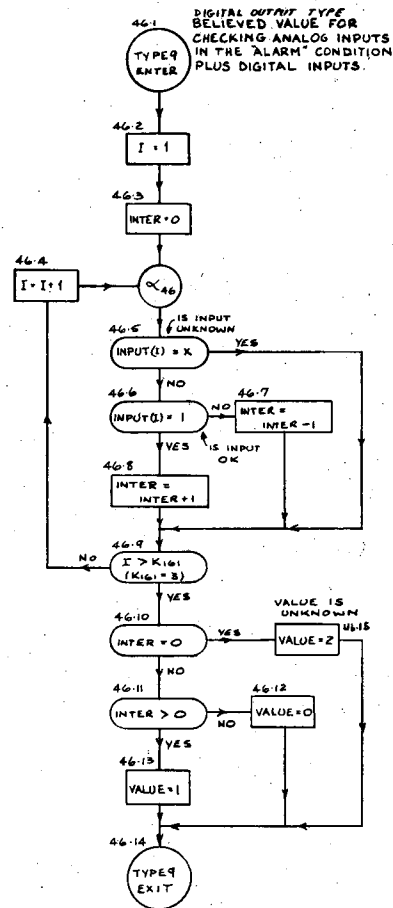
## THE ELECTRICITY COMMISSION OF N.S.W.

LIDDELL POWER STATION  
 AUTOMATIC TURBINE START FLOW CHART  
 SHEET 45  
 BELIEVED VALUE ROUTINES

SCALE		DATE	
DRAWN	DBL		11/10/69
TRACED			
CHECKED	46		
DATE	10/10/69		

LD267255 CII

AMENDMENTS  
 1. REVISION PRIOR TO  
 PROGRAMMING  
 BY N.S.W. E.C.C. 96.  
 BASED ON P. 70.



## NOTES

### TYPE 9

#### FOR ANALOG INPUTS

1 = OK (NOT IN ALARM) [QUALITY = 0]

0 = IN ALARM (QUALITY = 1 OR 2)

X = QUALITY > 2 OR NO INPUT ALLOCATED

#### FOR DIGITAL INPUTS

1 = OK OR TRUE

0 = ALARM CONDITION OR FALSE

X = UNKNOWN OR INPUT NOT ALLOCATED

#### FOR VALUE

1 = OK

0 = NOT OK

2 = UNKNOWN

### TYPE 10

#### FOR DIGITAL INPUTS 1-3

1 = TRUE

0 = FALSE

X = UNKNOWN

- = ANY CONDITION

#### FOR ANALOG INPUT 4

1 = > 2500 R.P.M.

0 = < 2500 R.P.M.

X = UNKNOWN

- = ANY CONDITION

#### FOR VALUE

0 = FALSE

1 = TRUE

### TYPE 11

#### FOR DIGITAL INPUTS 1-4

1 = TRUE

0 = FALSE

X = UNKNOWN

- = ANY CONDITION

#### FOR VALUE

0 = FALSE

1 = TRUE

## FLAG TABLE

NAME	DESCRIPTION	EXTERNAL FLAGS ONLY	
		SET BY PROGRAM	RESET BY PROGRAM
INPUT 1-N	Value of each input (Refer Data Tables)	-	-
I	Index for Inputs	-	-
INTER	Intermediate Value	-	-
VALUE	Value of B.V.	-	-

AMENDMENTS  
1. REVISION FROM  
TO PROGRAMMING  
ON N.S. 100 4  
A.S.E. CHART 11  
2. TYPE 10 11  
A.S.E. CHART 11  
3. TYPE 10 11  
A.S.E. CHART 11  
4. TYPE 10 11  
A.S.E. CHART 11

## THE ELECTRICITY COMMISSION OF N.S.W.

LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 46  
BELIEVED VALUE ROUTINES

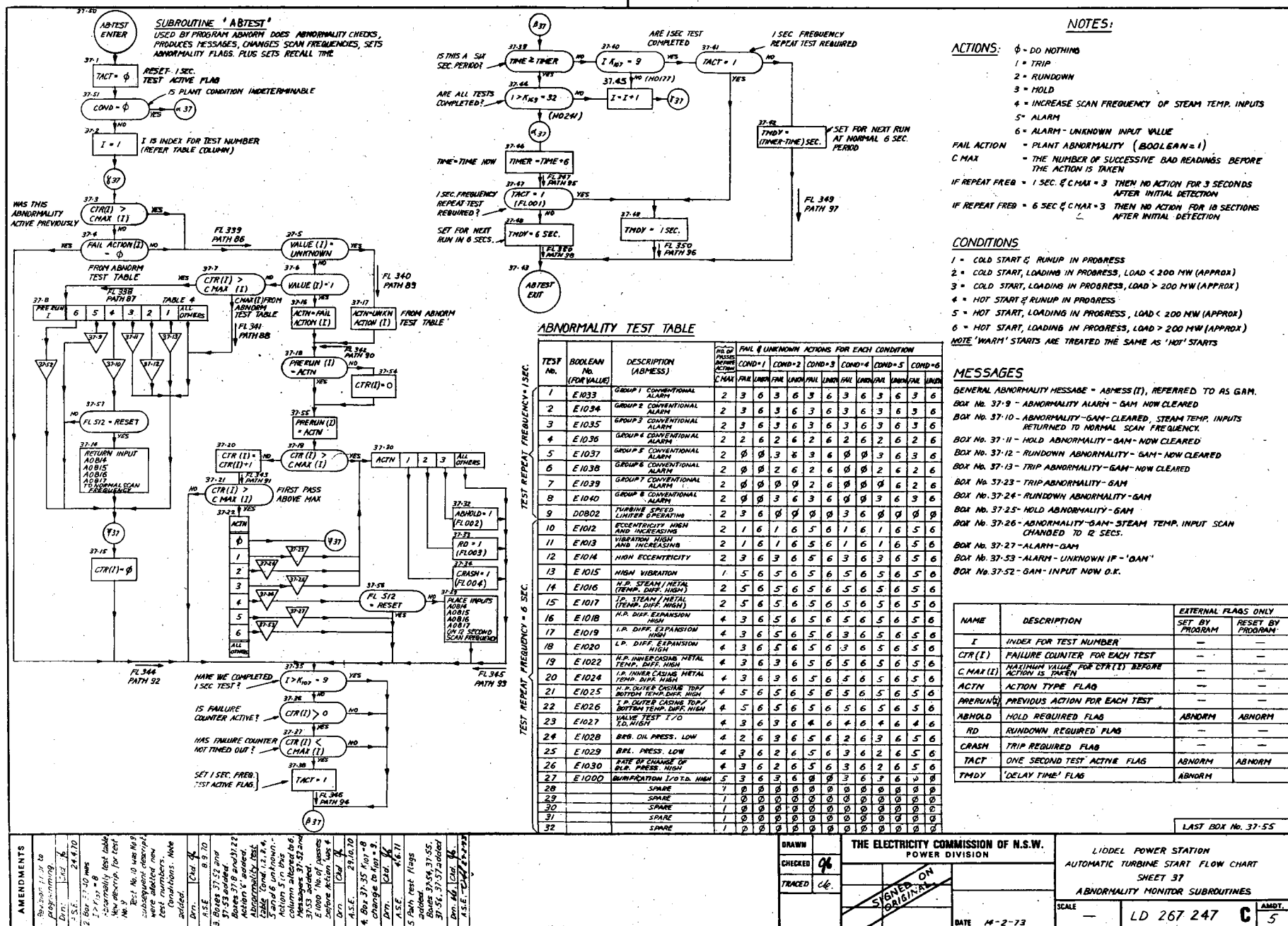
SCALE	DATE	DATE
DRAWN DB	DATE	10/10/69
TRACED	DATE	
CHECKED J.C.	DATE	
DATE 10/10/69	DATE	
LD 267256 C/2		

## **APPENDIX J**

### **PLANT PARAMETER MONITORING**

#### **PROGRAM FLOWCHART**







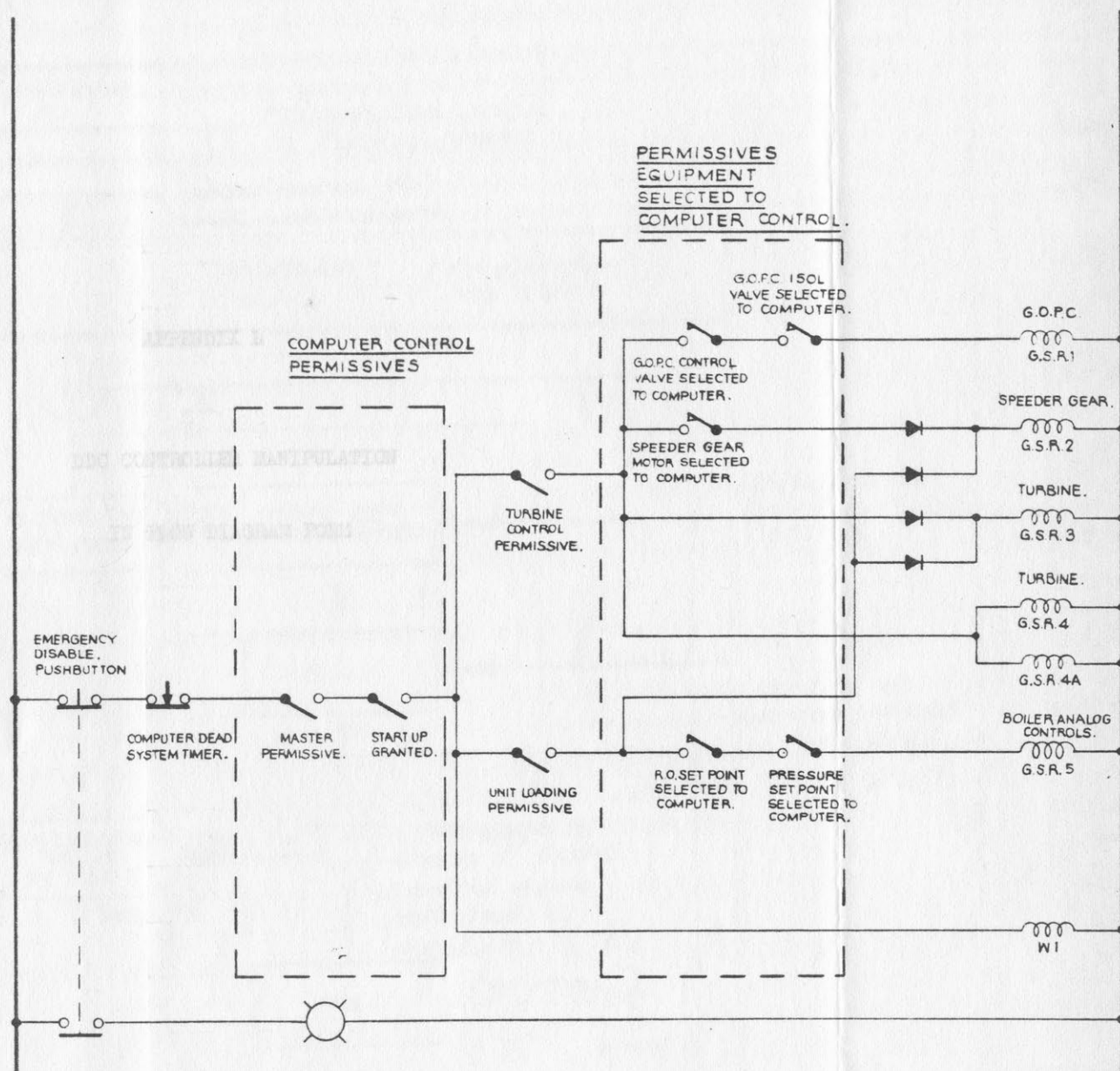
## APPENDIX K

### CONTROL HARDWARE DETAILS

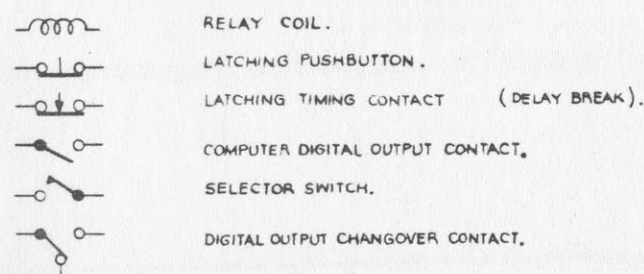
# COMPUTER CONTROL MASTER SELECTION

+ 50V. D.C.

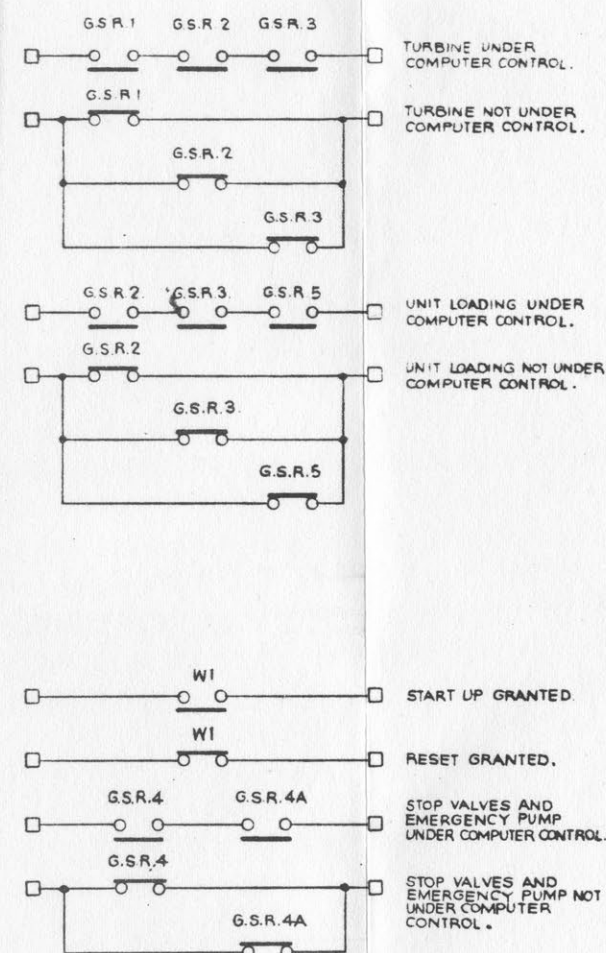
-50V.D.C.



## LEGEND

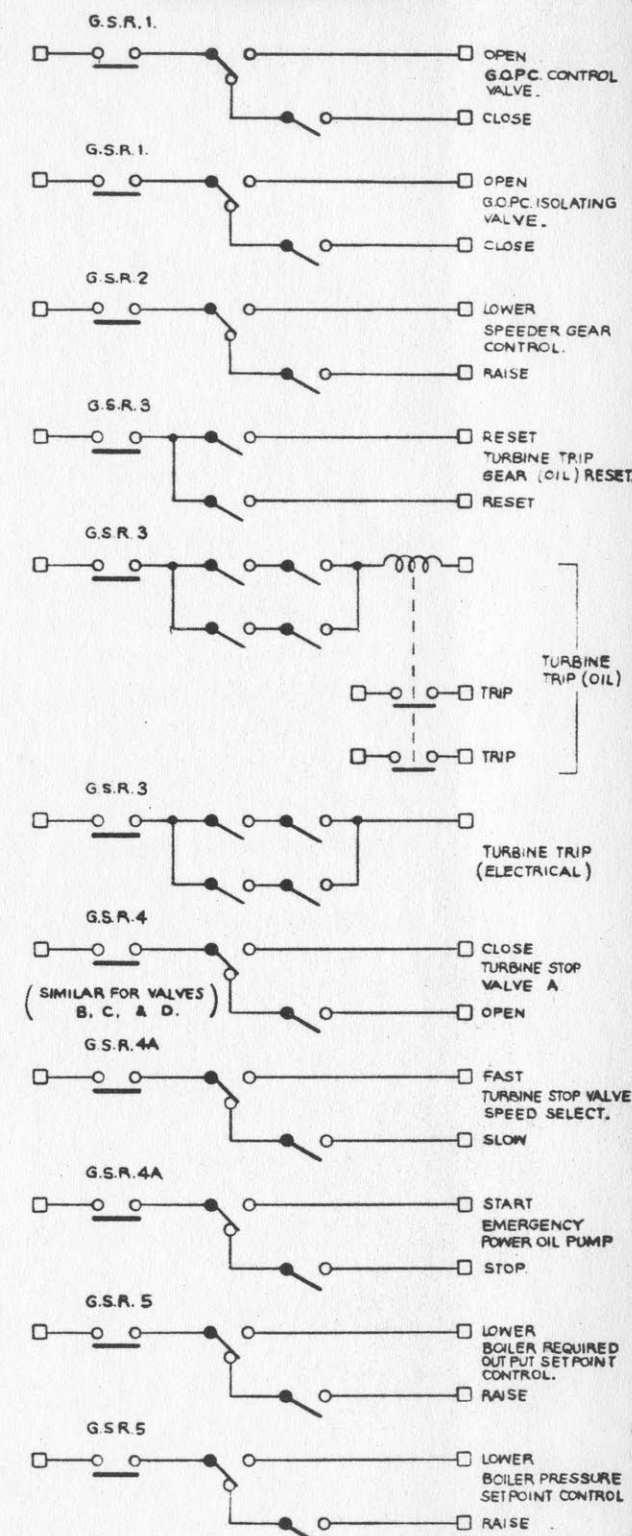


# COMPUTER INPUTS.



NOTE: COMPUTER INPUTS ORIGINATING FROM THE RUNUP PANEL EXCLUDED.

# COMPUTER OUTPUTS. FOR CONTROL FUNCTIONS



LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE RUN-UP & LOADING  
CONTROL HARDWARE PROTECTION DETAILS

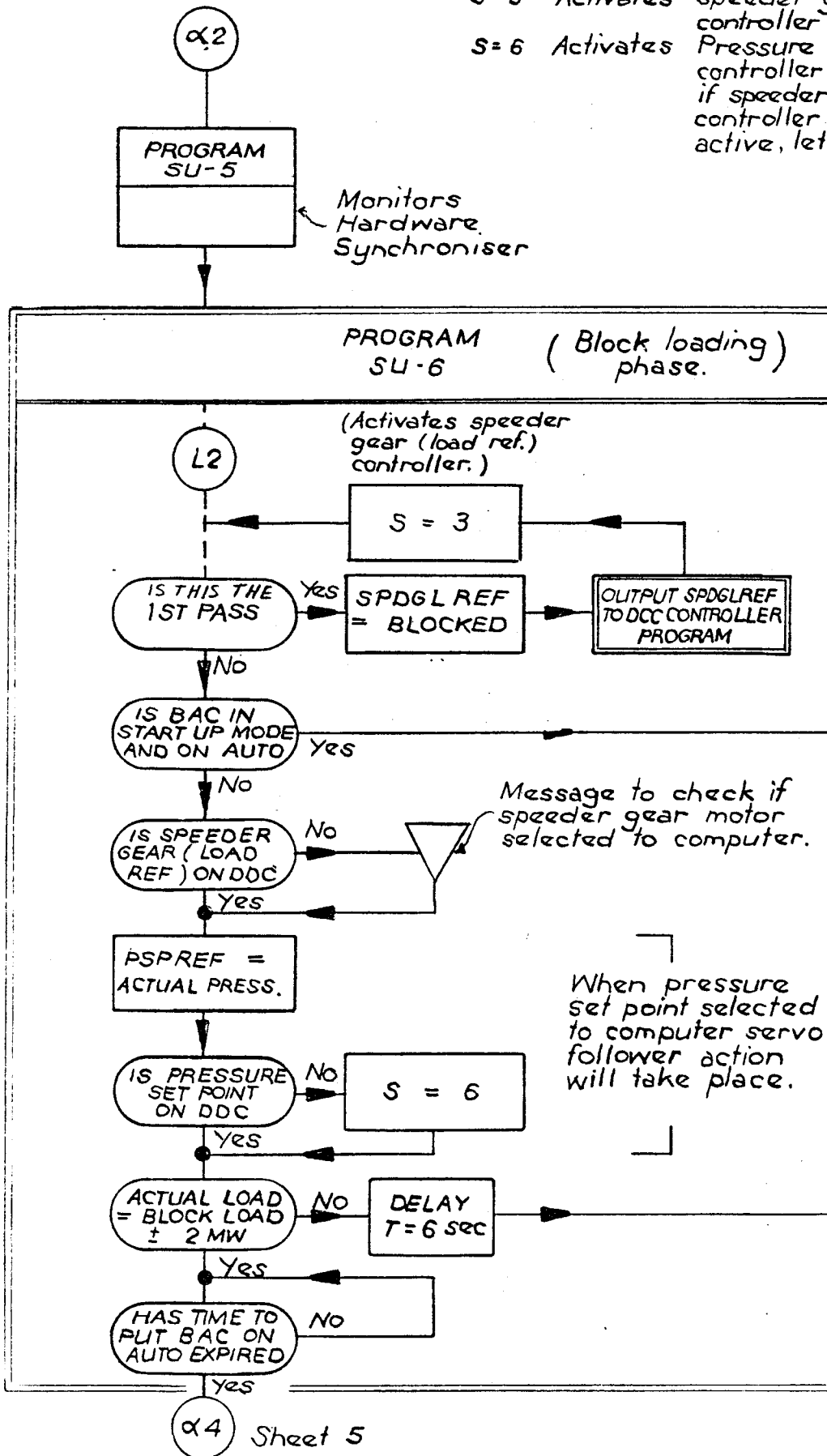
## APPENDIX L

### DDC CONTROLLER MANIPULATION IN FLOW DIAGRAM FORM



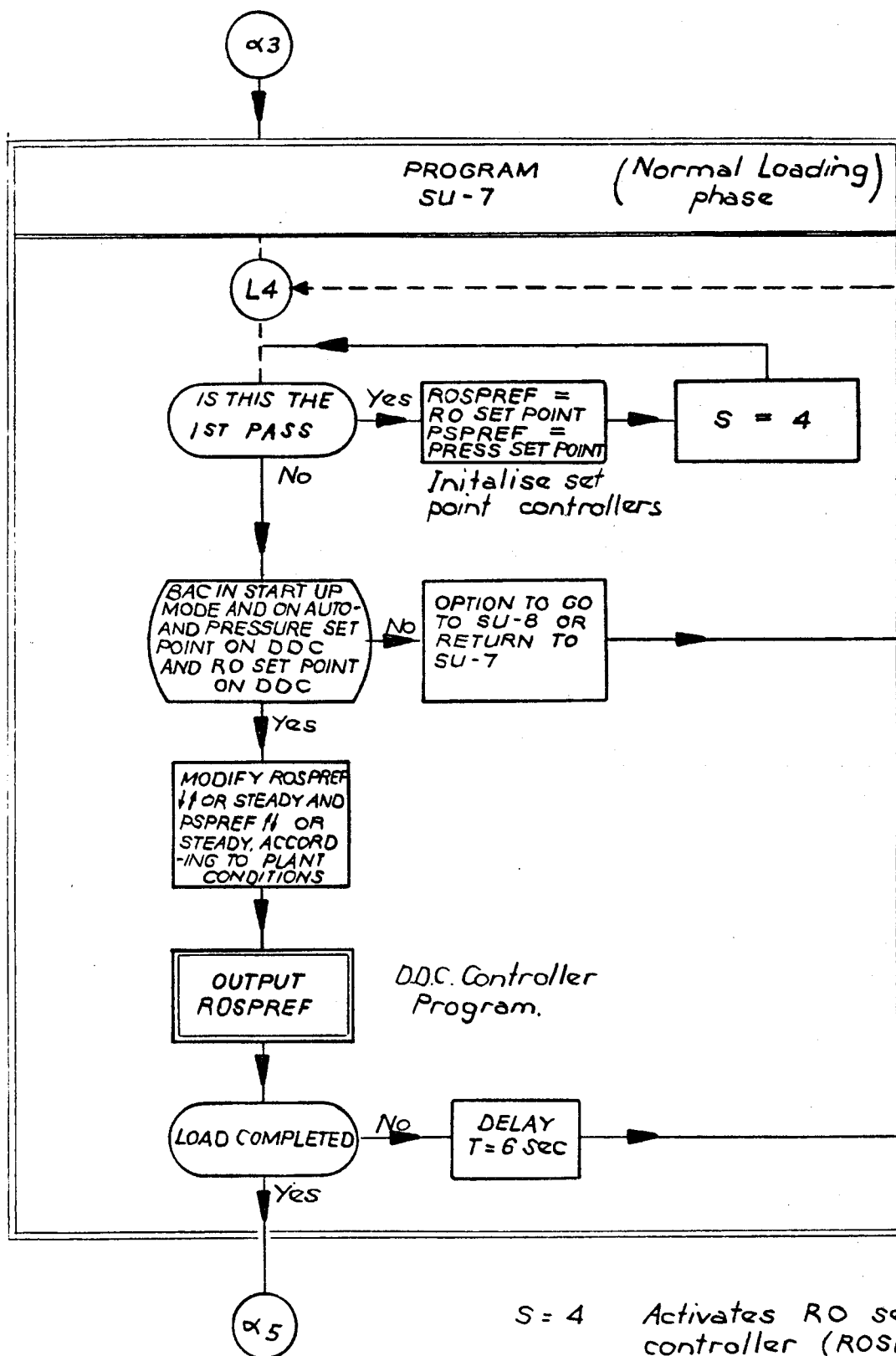


S = 3 Activates speeder gear (Load ref.) controller - (SPDGL REF)  
 S = 6 Activates Pressure set point controller (PSPREF) and if speeder gear (Load ref.) controller (SPDGL REF) active, let it alone.



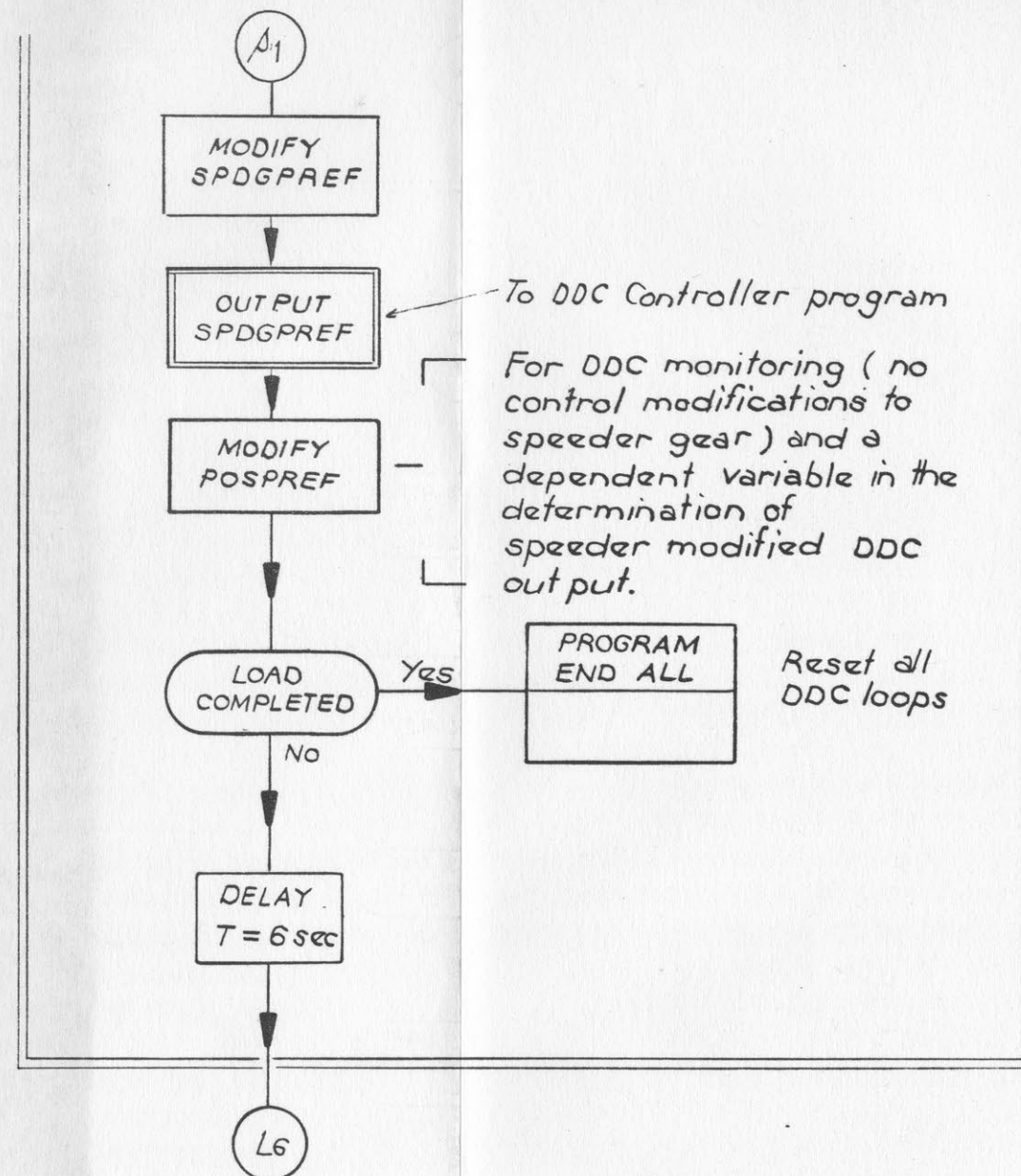
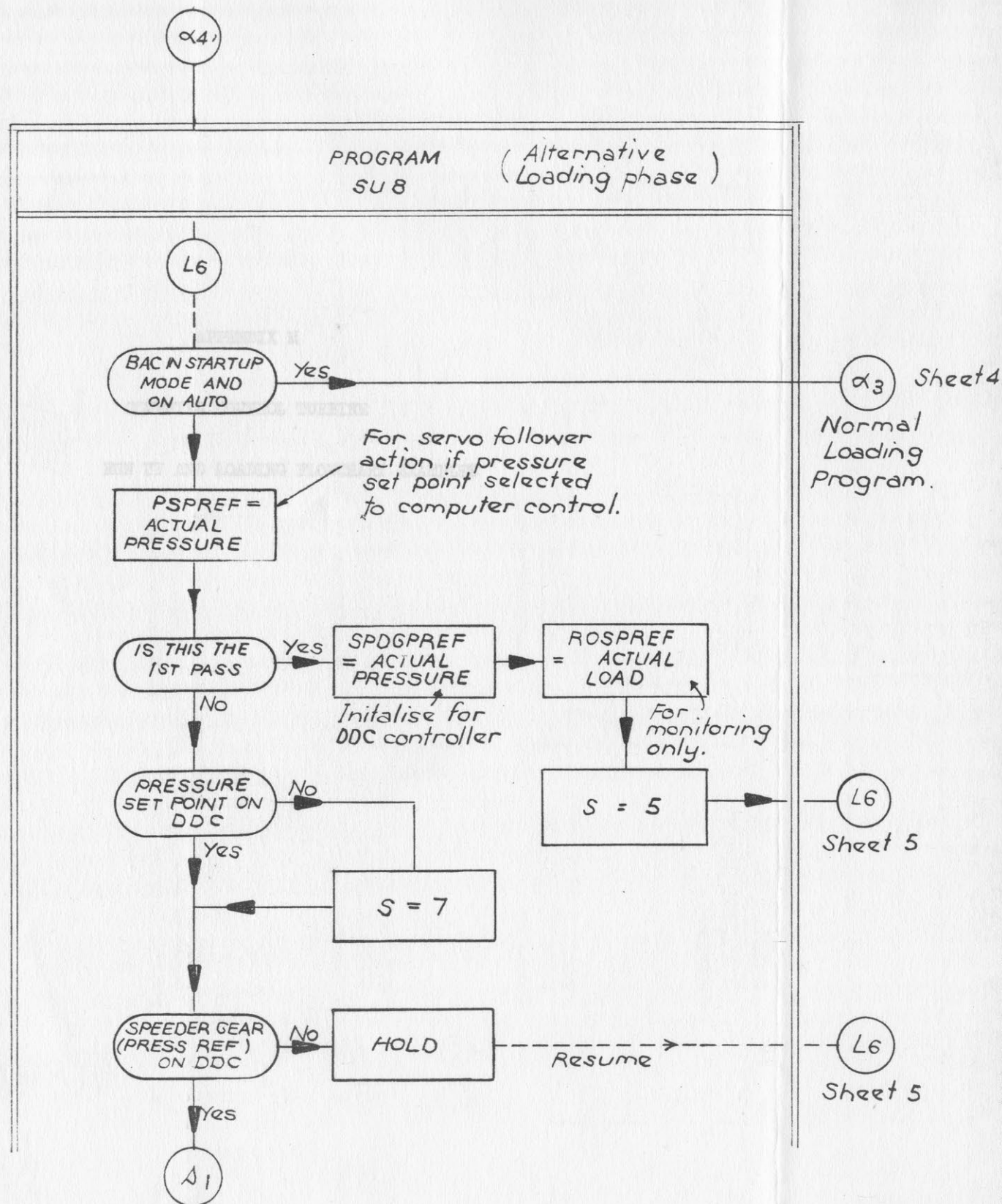
DRAWN				LIDDELL POWER STATION COMPUTER CONTROLLED TURBINE RUNUP AND LOADING DDC CONTROLLER MANIPULATION	
CHECKED	JC				
SHT	3				
				SCALE	
		DATE		E	AMDT.





S = 4 Activates RO set point controller (ROSPREF) and Pressure set point controller (PSPREF)

DRAWN					LIDDELL POWER STATION COMPUTER CONTROLLED TURBINE RUNUP AND LOADING DDC CONTROLLER MANIPULATION
CHECKED	JC				
SHT	4				
		DATE			SCALE
					E
					AMDT.



S = 5 Activates Pressure set point controller (PSPREF) and Speeder gear (pressure reference) controller (SPDGPREF)

S = 7 Activates Pressure set point controller (PSPREF) if speeder gear (pressure reference) controller (SPDGPREF) active, let it alone.

AMENDMENTS	DRAWN					LIDDELL POWER STATION COMPUTER CONTROLLER TURBINE RUNUP AND LOADING DDC CONTROLLER MANIPULATION		
	CHECKED	JC						
	SHT	5						
						SCALE		AMDT
					DATE		D	

## APPENDIX M

### COMPUTER CONTROL TURBINE

#### RUN UP AND LOADING FLOWCHART EXAMPLES

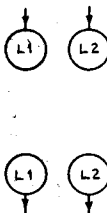
# 1. BEGIN AND END SYMBOLS.

A large circle is used to denote the beginning and the end of a program or subroutine. The symbolic name of the program or subroutine is given in the upper half of the circle.



# 2. LOGICAL CONNECTORS.

A small circle with a letter followed by a number is used to denote a logical break in the flow of the flowchart. This symbol will always be a checkpoint.



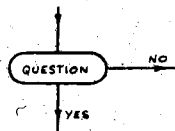
# 3. TOPOLOGICAL CONNECTORS.

A small circle with a greek letter followed by a number is used to transfer from one place in the flowchart to another.

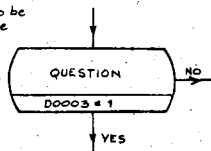


# 4. QUESTION BOX.

A box with rounded ends is used to contain questions answerable by 'YES' (True) or 'NO' (False). The position of 'yes' and 'no' exits does not matter but the exits must be clearly marked.

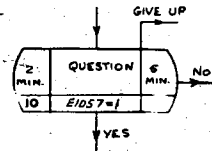


The question box may also be shown with a horizontal line in the box. BV or input numbers will be shown below this line. In the case of a digital type question the desired state will be shown.



# 5. QUESTION-ACTION BOX.

For details see Sheet 2 - Standard Logic.



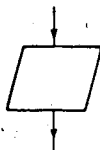
# 6. SUBROUTINE BOX.

Used to denote entry into a subroutine with a return to the main program at the outlet of the subroutine box.



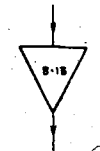
# 7. ACTION BOX.

A box with inclined sides is used to denote outputs external to the computer itself. This box is not used for messages.



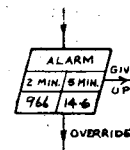
# 8. MESSAGE BOX.

This box will indicate that an operator message is to be produced. The box number will identify the message and will be shown inside the box. All messages shall include time of event (hour, min, sec.).



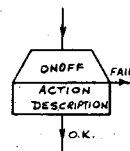
# 9. ALARM BOX.

For details see Sheet 2 - Standard Logic.



# 10. PLANT OPERATION BOX.

For details see Sheet 3 - Standard Logic.



# 11. MODIFICATION BOX.

Used to denote changes in the specification of the data processing part of the computer system. eg. scan frequency changes, alarm limit change, etc.

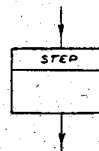


# 12. MISCELLANEOUS OPERATION BOX.

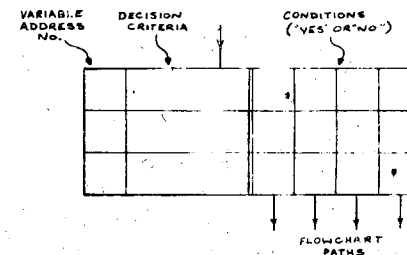
Used to denote operations not covered by other symbols. eg. arithmetic operations, time delays, output to other programs etc.



For commonly used operations such as STEP or DELAY, the operation will be shown above a horizontal line in the top part of the box.

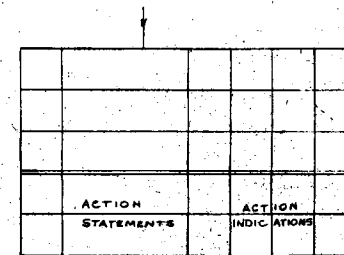


# 13. DECISION TABLES.



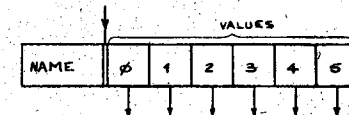
Used to specify complex decisions involving many parameters. The decision tables are examined from left to right; the first condition found true determines the flowchart path.

# 14. DECISION TABLES WITH ACTION SPECIFICATION.



Used to specify complex decisions and type of action to be taken. The portion of the decision table above the double line is the same as in 13 above. Action indicators show if the action statement is to be implemented when the related condition is true.

# 15. SWITCH BOX.



Used to specify the program paths to be taken when a software switch is set to a value. The name of the switch is given in the left hand side of the box.

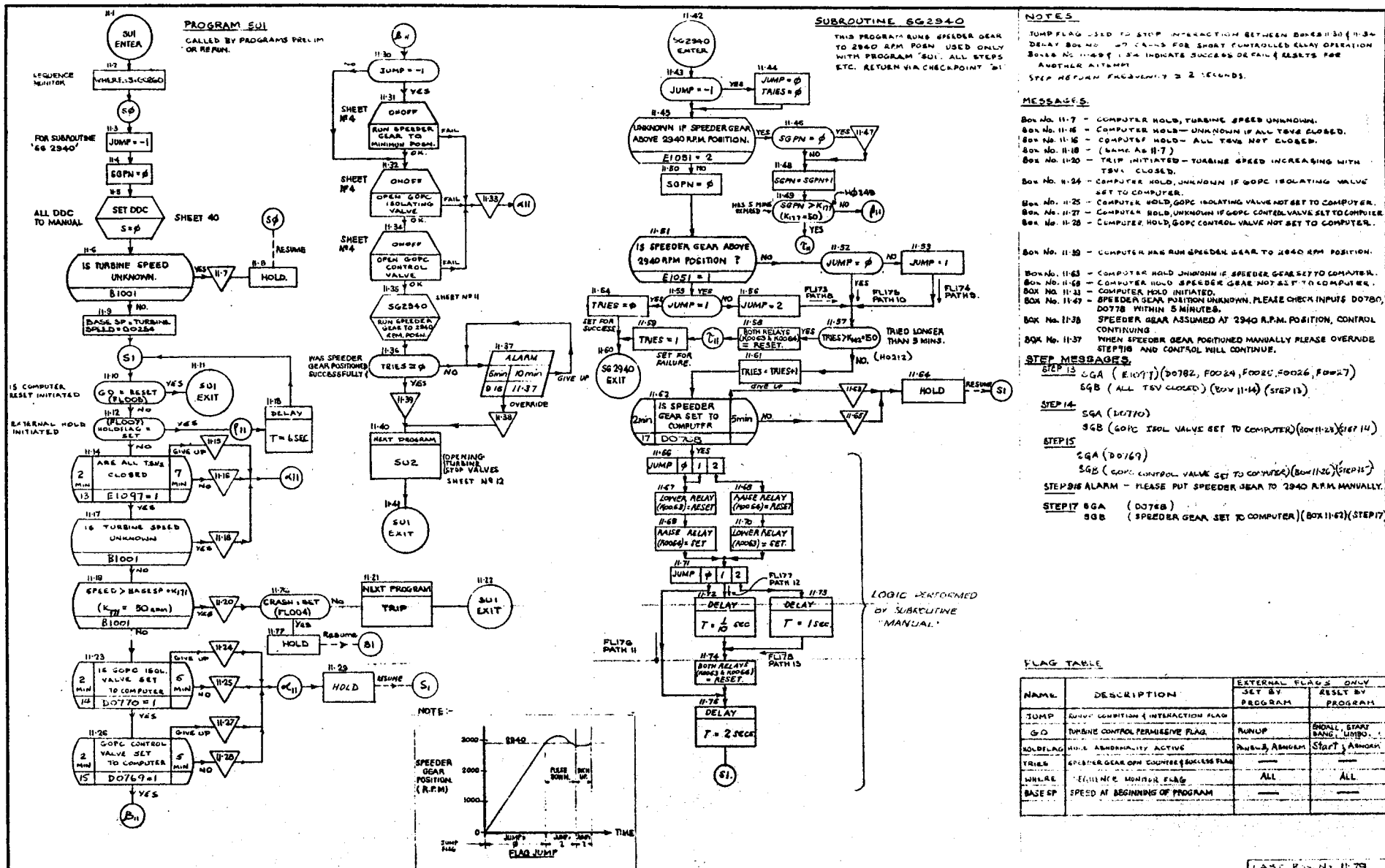
REVISIONS	REVISION PRIOR TO PROGRAMMING
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10

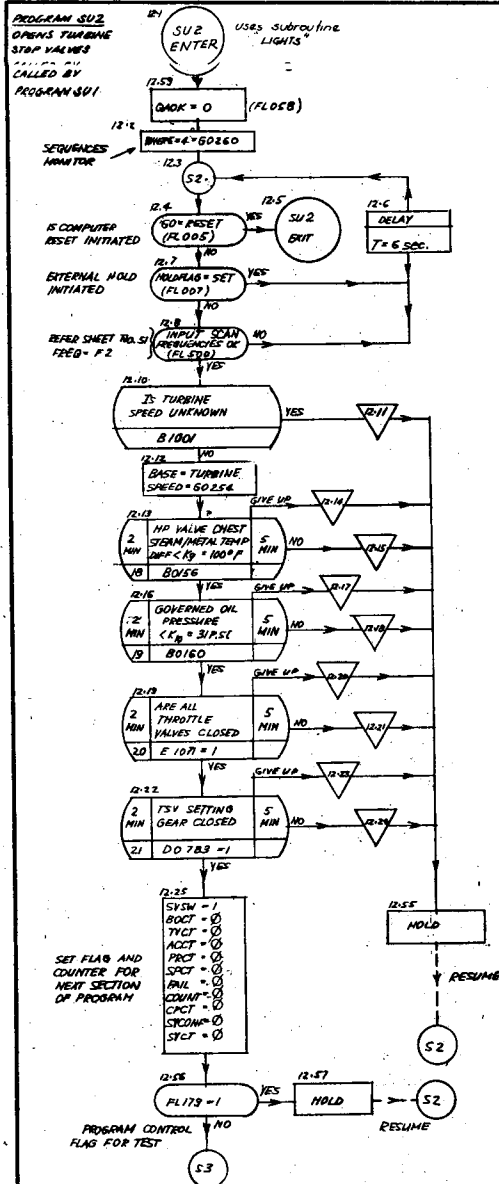
# THE ELECTRICITY COMMISSION OF N.S.W.

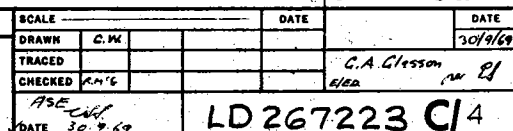
LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 1  
SYMBOLS

SCALE	DATE	DATE
DRAWN DBL		30/9/69
TRACED		
CHECKED RM'C		
ASD		
DATE 30.9.69		

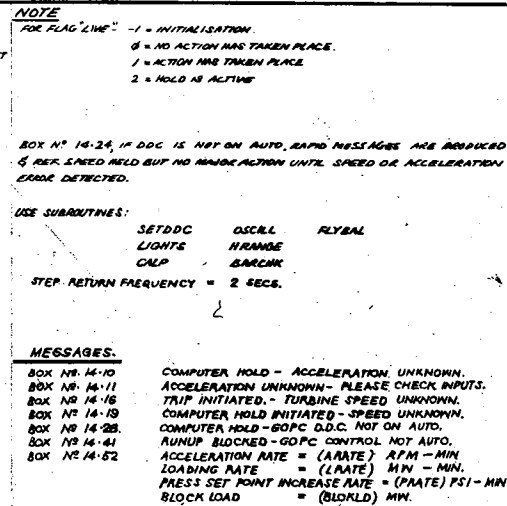
G.A. Glasson  
EIDED  
LD 267210 C12







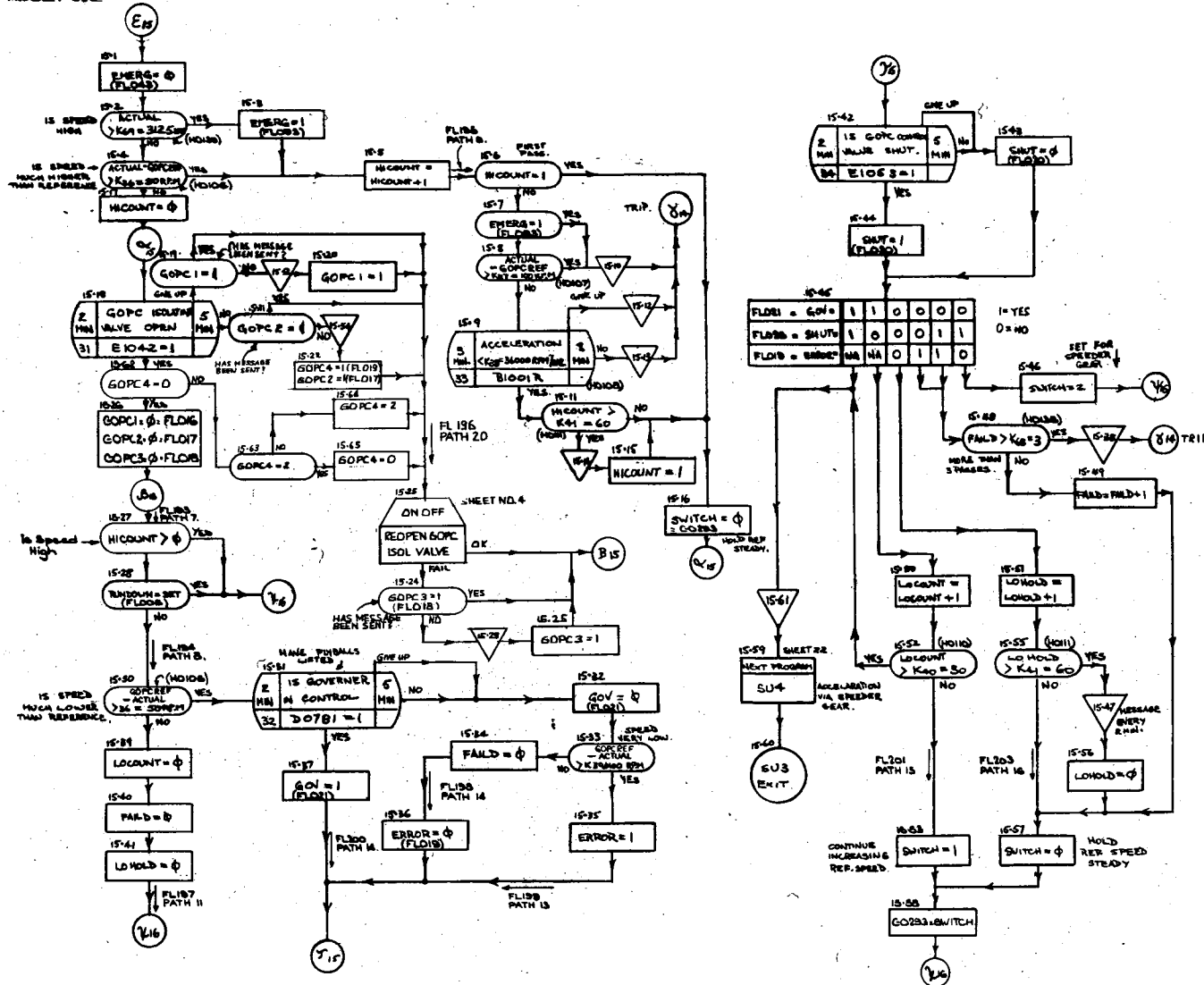




FLAG TABLE		EXTERNAL FLAGS ONLY	
NAME	DESCRIPTION	SET BY PROGRAM	RESET BY PROGRAM
LOHOLD	Counter for Box N° 15-47	---	---
LIVE	Direction Indicator + Active Flag	SU2 - SU3	SU3 - SU4
FAULT	Counter for Box N° M-41	---	---
HICOUNT	Counter for High Speed Errors	---	---
LOCOUNT	Counter for Box N° 15-45	---	---
FAILD	Counter for Box N° 15-37	---	---
MESS	Message type flag for Sheet N° 18	---	---
PROGND	Hold in progress flag	---	---
PRALL	Counter for Box N° 17-3	---	---
XCESS	Counter for box N° 17-8	---	---
GOPC1-3	---	---	---
GO	Contl. Permissive Flag	ROUND.	EMBALL LINE START - BAND
INCR	Normal Reference Increment	---	---
RDAMT	Random Reference Increment	---	---
SWITCH	Action Type Switch	---	---
ACTUAL	Value of Actual Speed	---	---
WHERE	Sequence Monitor Flag	ALL	ALL



PROGRAM SUB.



NOTE.

FOR SWITCH -  $\phi$  = HOLD REF STEADY  
1 = NORMAL  
2 = SPEEDER GEAR

MESSAGES

BOX N° 15-10 - TRIP INITIATED - SPEED HIGH.  
BOX N° 15-12 - TRIP INITIATED - SPEED & ACCELERATION UNKNOWN.  
BOX N° 15-13 - TRIP INITIATED - SPEED & ACCELERATION HIGH.  
BOX N° 15-14 - ALARM-FAULT IN GPC CONTROL - SPEED ERROR.  
BOX N° 15-22 - CONTROL CONTINUING.  
BOX N° 15-35 - TRIP INITIATED - SPEED BELOW REFERENCE.  
BOX N° 15-47 - ALARM-FAULT IN GPC CONTROL - SPEED ERROR.  
BOX N° 15-52 - UNKNOWN IF GPC ISOLATING VALVE OPEN-ATTEMPTING TO OPEN VALVE.  
BOX N° 15-54 - GPC ISOLATING VALVE NOT OPEN-ATTEMPTING TO REVALUE  
BOX N° 15-61 - CONTROL CONTINUING VIA SPEEDER GEAR.

STEP MESSAGES

STEP B1 - SGA (E1042) (D0776, D0777)  
SGA (GPC ISOLATING VALVE OPEN) (BOX 15-52) (STEP 30)  
STEP B2 - SGA (D0781)  
SGA (GOVERNOR IN CONTROL) (BOX 15-21) (STEP B1)  
STEP B3 - SGA (D0781) (AD358, AD359, AD360)  
SGA (ACCELERATION > K48) (BOX 15-11) (STEP B2)  
STEP B4 - SGA (E1053) (D0773, D0777)  
SGA (GPC CONTROL VALVE SHUT) (BOX 15-53) (STEP B3)

FLAG TABLE

NAME	DESCRIPTION	SET BY PROGRAM	RESET BY PROGRAM	EXTERNAL FLAG ONLY
EMERG	Speed High Flag			
HICOUNT	Counter for High Speed Errors			
ACTUAL	Value of Actual Speed			
RUNDOWN	Run-down Abnormality Active		Abnormal	Start
LOCOUNT	Counter for Box N° 15-52			
LOHOLD	Counter for Box N° 15-53			
REED	Speed Very Low Flag			
SHUT	GPC Control Valve Shut Flag			
FAILD	Counter for Box N° 15-48			
SWITCH	Action type switch			
GOPC1=3	MESSAGE SENT FLAG			
GOV	Governor in Control Flag			

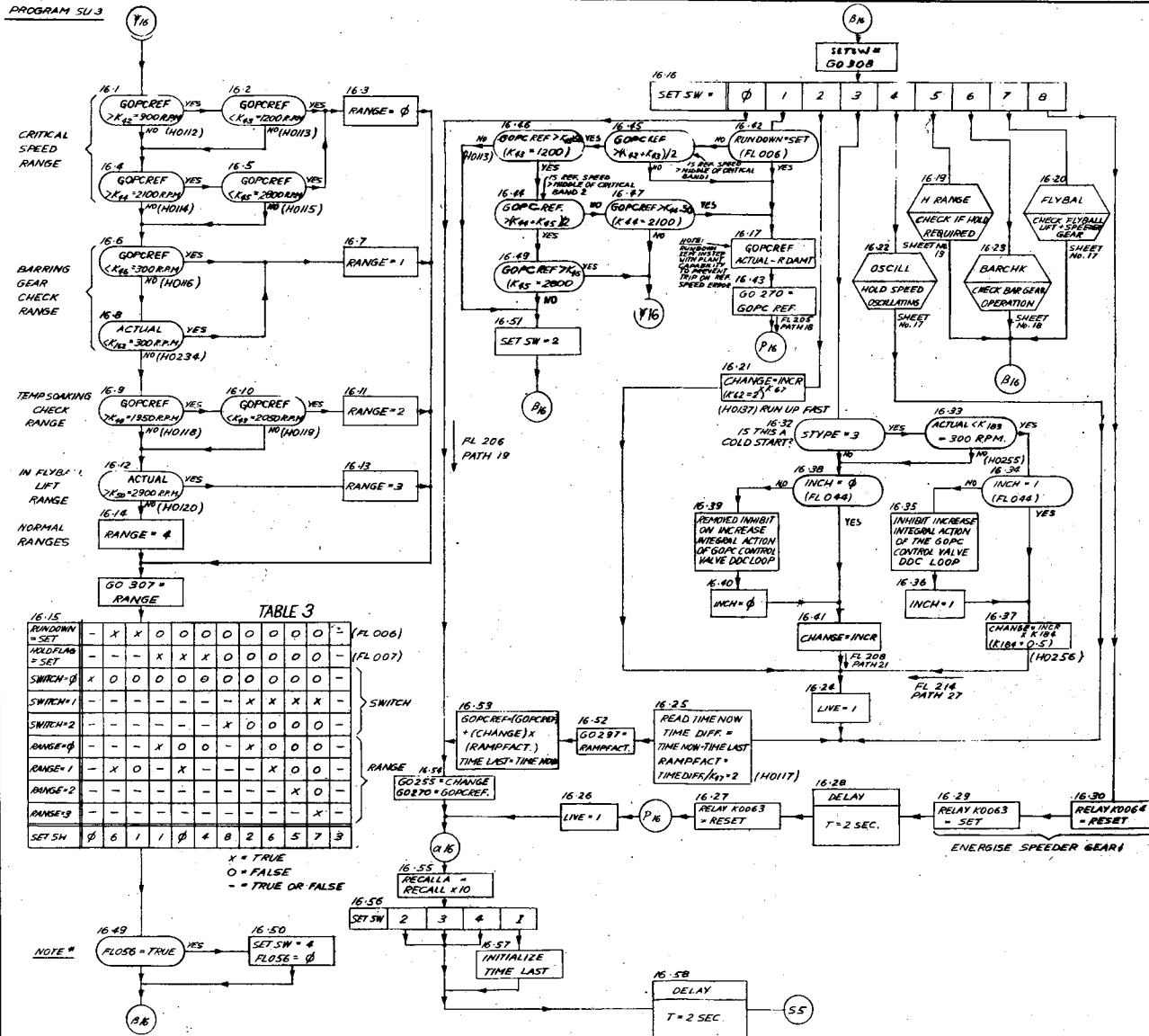
AMENDMENTS  
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2. Business Unit  
3. Business Unit  
4. Business Unit  
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96. Business Unit  
97. Business Unit  
98. Business Unit  
99. Business Unit  
100. Business Unit

THE ELECTRICITY COMMISSION OF N.S.W.  
LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOWCHART  
SHEET 15  
ACCELERATION VIA GPC.

SCALE SIGNED ON ORIGINAL DATE  
DRAWN N.S. DATE  
TRACED DATE  
CHECKED A.M.G. DATE  
DATE V.S.S. 30.9.69  
LAST BOX N° 15-65  
DATE 30.9.69  
G.A. GLASSON  
E.S.

LD267225 C/3

PROGRAM SU.3



NOTE  
FOR SWITCH - 0 = HOLD REF STEADY } FOR GOPC  
1 = NORMAL  
2 = SPEEDER GEAR  
3 = RUN DOWN  
4 = RUN UP  
5 = RUN UP FAST  
6 = HOLD (OSCILLATING)  
7 = HOLD CHECKS  
8 = BARRING GEAR CHECKS  
9 = FLYBALL LIFT CHECKS  
10 = SPEEDER GEAR

FOR SETSW - 0 = HOLD REF SPEED STEADY  
1 = RUN DOWN  
2 = RUNUP FAST  
3 = RUNUP NORMAL  
4 = HOLD (OSCILLATING)  
5 = HOLD CHECKS  
6 = BARRING GEAR CHECKS  
7 = FLYBALL LIFT CHECKS  
8 = SPEEDER GEAR

BOX NO.16-21 GIVES INCREASED RATE OF ACCELERATION THROUGH CRITICAL SPEED RANGES.

FLAG TABLE

NAME	DESCRIPTION	EXTERNAL FLAG ONLY	SET BY PROGRAM	RESET BY REQUEST
RANGE	OPERATION RANGE			
ACTUAL	VALUE OF ACTUAL SPEED			
RUNDOWN	RUNDOWN ABNORMALITY ACTIVE	ABNORM.		ABNORM. START
HOLD FLAG	HOLD ABNORMALITY ACTIVE	PANEL 3 ABNORM. START		ABNORM. START
SWITCH	ACTION TYPE SWITCH			
SETSW	CHECKS - ACTIONS SWITCH			
CHANGE	CHANGE INCREMENT OF REF. SPEED			
RDANT	RUNDOWN REFERENCE INCREMENT			
INCR	NORMAL REFERENCE INCREMENT			
LIVE	DIRECTION INDICATOR - ACTIVE FLAG	SU.2, SU.3, SU.3, SU.4		

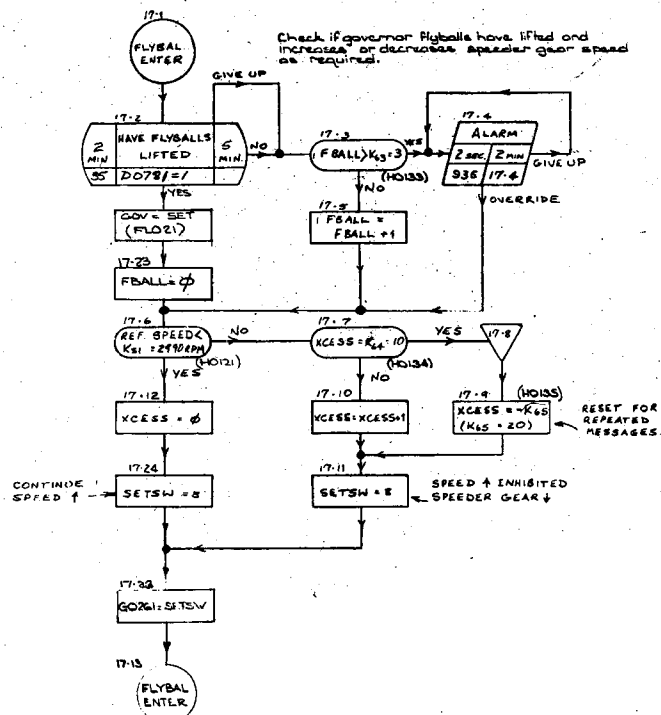
NOTE\*  
FLOSG IS SET IN SUBROUTINE 'H RANGE' IF ANALOGS THAT DETERMINE THE HEAT SOAK PERIOD ARE UNKNOWN. FLOSG IS SET TO FORCE 'SETSW' TO A'4' TO ACHIEVE A HOLD AND CONTROLLED OSCILLATION OF TURBINE SPEED. WITHOUT THIS FEATURE SPEED IS HOLD STEADY WAITING FOR ANALOGS TO BE RESTORED OR OVERRIDDEN.

AMENDMENTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1. REVISION	2. REVISION	3. REVISION	4. REVISION	5. REVISION	6. REVISION	7. REVISION	8. REVISION	9. REVISION	10. REVISION	11. REVISION	12. REVISION	13. REVISION	14. REVISION	15. REVISION	16. REVISION	17. REVISION	18. REVISION	19. REVISION	20. REVISION	21. REVISION	22. REVISION	23. REVISION	24. REVISION	25. REVISION	26. REVISION	27. REVISION	28. REVISION	29. REVISION	30. REVISION	31. REVISION	32. REVISION	33. REVISION	34. REVISION	35. REVISION	36. REVISION	37. REVISION	38. REVISION	39. REVISION	40. REVISION	41. REVISION	42. REVISION	43. REVISION	44. REVISION	45. REVISION	46. REVISION	47. REVISION	48. REVISION	49. REVISION	50. REVISION	51. REVISION	52. REVISION	53. REVISION	54. REVISION	55. REVISION	56. REVISION	57. REVISION	58. REVISION	59. REVISION	60. REVISION	61. REVISION	62. REVISION	63. REVISION	64. REVISION	65. REVISION	66. REVISION	67. REVISION	68. REVISION	69. REVISION	70. REVISION	71. REVISION	72. REVISION	73. REVISION	74. REVISION	75. REVISION	76. REVISION	77. REVISION	78. REVISION	79. REVISION	80. REVISION	81. REVISION	82. REVISION	83. REVISION	84. REVISION	85. REVISION	86. REVISION	87. REVISION	88. REVISION	89. REVISION	90. REVISION	91. REVISION	92. REVISION	93. REVISION	94. REVISION	95. REVISION	96. REVISION	97. REVISION	98. REVISION	99. REVISION	100. REVISION	
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DRAWN	CHECKED	TRACED	DATE	14.2.73	SCALE	LD 267226	C	4
THE ELECTRICITY COMMISSION OF N.S.W. POWER DIVISION					LIDDELL POWER STATION AUTOMATIC TURBINE START FLOW CHART SHEET 15 ACCELERATION VIA GOPC			
STAGED ON ORIGINAL					DATE 14.2.73			

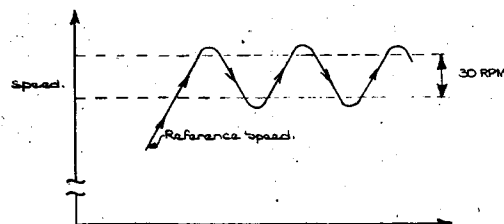
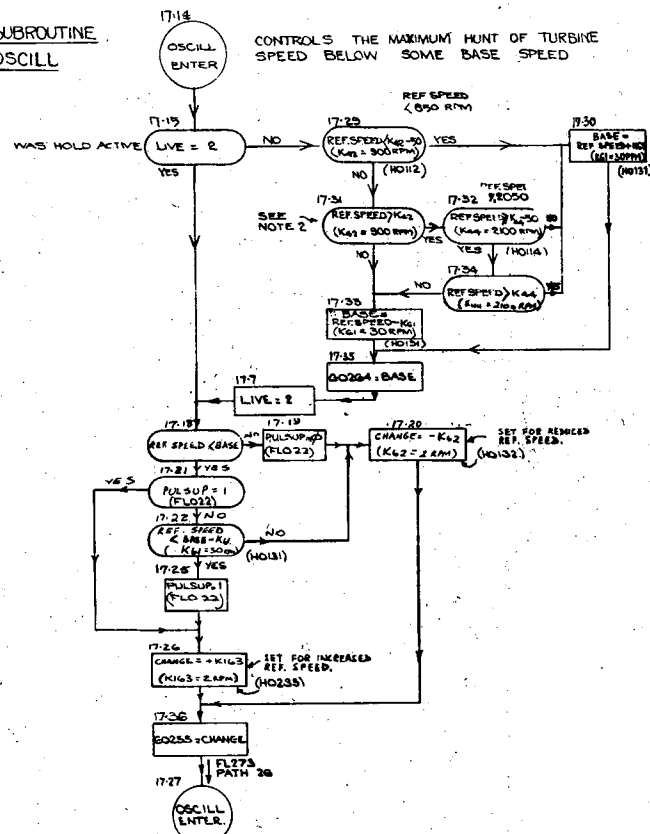
LAST BOX NO. 16-58

SUBROUTINE  
FLYBAL



SUBROUTINE  
OSCILL

CONTROLS THE MAXIMUM HUNT OF TURBINE  
SPEED BELOW SOME BASE SPEED

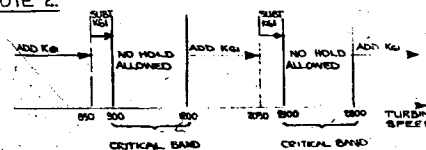


NOTE 1

SUBROUTINE FLYBAL  
USED BY PROGRAM "SU3" IN RANGE ABOVE 2,990 RPM  
WITH SPEED INCREASES CALLED.

SUBROUTINE OSCILL  
USED BY PROGRAM "SU3". PRODUCES SLOW HUNT  
DURING HOLD.

NOTE 2.



MESSAGES.

17.4 - SPEED HOLD, FLYBALLS HAVE NOT LIFTED - OVERRIDE VIA STEP 936 OR RETURN TO MANUAL

17.5 - ATTEMPTS TO CONTROL WITH SPEEDER GEAR UNSUCCESSFUL, SUGGEST OPERATOR RETURN TO MANUAL CONTROL.

### STEP MESSAGES

STEP 35 - SGA (DO 781)  
- SGB (FLYBALLS HAVE LIFTED) (BOX 172) (STEP 34)  
STEP 35G - NO MESSAGE

FLAG TABLE

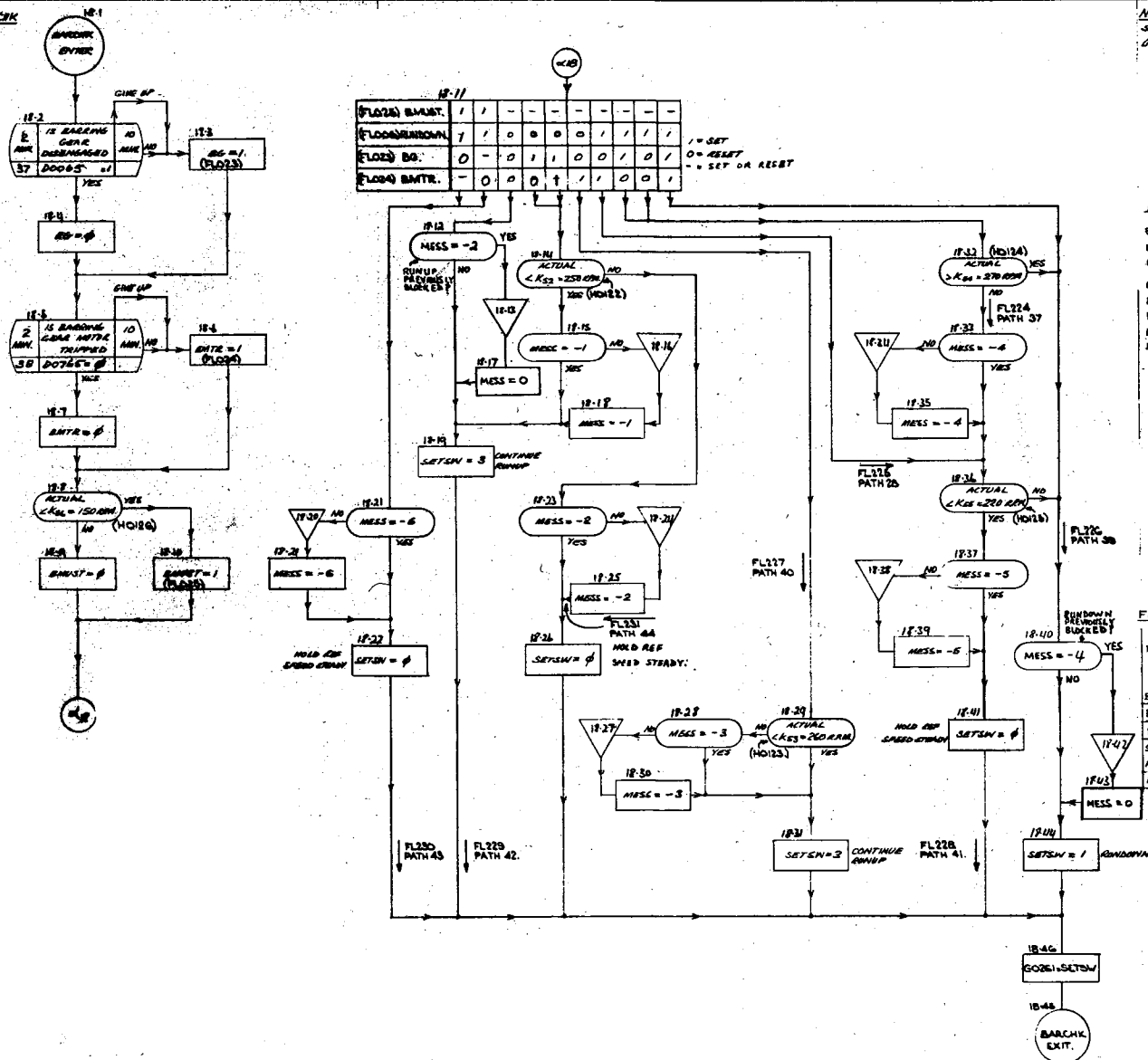
DESCRIPTION		EXTERNAL FLAGS ONLY	
NAME	DESCRIPTION	SET BY PROGRAM	RESET BY PROGRAM
FDALL	Counter for Box NR17:3	---	---
ICLESS	Counter for Box NR17:8	---	---
SETSW	Checks 6 Actions Flag. (REFER SHEET 16)	---	---
LIVE	Direction, Inhibitor + Active Flag.	SUB, SUB	SUB, SUB
PULSUP	Hold Oscillation Direction Flag.	---	---
CHANGE	Change Increment to Reference Speed	---	---
BASE	Speed at beginning of program	---	---

AMENDMENTS
1 REVISION PRICED TO PROGRAMMING. BORN N.S. CKO 4. A.S.E. 11/25/73 2 BOX 174. STEP 36 BORN 11/19/73 CKO 4. A.S.E. 11/25/73 3 BOX 174. 11/25/73 4 11/25/73 5 11/25/73 6 11/25/73 7 11/25/73 8 11/25/73 9 11/25/73 10 11/25/73 11 11/25/73 12 11/25/73 13 11/25/73 14 11/25/73 15 11/25/73 16 11/25/73 17 11/25/73 18 11/25/73 19 11/25/73 20 11/25/73 21 11/25/73 22 11/25/73 23 11/25/73 24 11/25/73 25 11/25/73 26 11/25/73 27 11/25/73 28 11/25/73 29 11/25/73 30 11/25/73 31 11/25/73 32 11/25/73 33 11/25/73 34 11/25/73 35 11/25/73 36 11/25/73 37 11/25/73 38 11/25/73 39 11/25/73 40 11/25/73 41 11/25/73 42 11/25/73 43 11/25/73 44 11/25/73 45 11/25/73 46 11/25/73 47 11/25/73 48 11/25/73 49 11/25/73 50 11/25/73 51 11/25/73 52 11/25/73 53 11/25/73 54 11/25/73 55 11/25/73 56 11/25/73 57 11/25/73 58 11/25/73 59 11/25/73 60 11/25/73 61 11/25/73 62 11/25/73 63 11/25/73 64 11/25/73 65 11/25/73 66 11/25/73 67 11/25/73 68 11/25/73 69 11/25/73 70 11/25/73 71 11/25/73 72 11/25/73 73 11/25/73 74 11/25/73 75 11/25/73 76 11/25/73 77 11/25/73 78 11/25/73 79 11/25/73 80 11/25/73 81 11/25/73 82 11/25/73 83 11/25/73 84 11/25/73 85 11/25/73 86 11/25/73 87 11/25/73 88 11/25/73 89 11/25/73 90 11/25/73 91 11/25/73 92 11/25/73 93 11/25/73 94 11/25/73 95 11/25/73 96 11/25/73 97 11/25/73 98 11/25/73 99 11/25/73 100 11/25/73 101 11/25/73 102 11/25/73 103 11/25/73 104 11/25/73 105 11/25/73 106 11/25/73 107 11/25/73 108 11/25/73 109 11/25/73 110 11/25/73 111 11/25/73 112 11/25/73 113 11/25/73 114 11/25/73 115 11/25/73 116 11/25/73 117 11/25/73 118 11/25/73 119 11/25/73 120 11/25/73 121 11/25/73 122 11/25/73 123 11/25/73 124 11/25/73 125 11/25/73 126 11/25/73 127 11/25/73 128 11/25/73 129 11/25/73 130 11/25/73 131 11/25/73 132 11/25/73 133 11/25/73 134 11/25/73 135 11/25/73 136 11/25/73 137 11/25/73 138 11/25/73 139 11/25/73 140 11/25/73 141 11/25/73 142 11/25/73 143 11/25/73 144 11/25/73 145 11/25/73 146 11/25/73 147 11/25/73 148 11/25/73 149 11/25/73 150 11/25/73 151 11/25/73 152 11/25/73 153 11/25/73 154 11/25/73 155 11/25/73 156 11/25/73 157 11/25/73 158 11/25/73 159 11/25/73 160 11/25/73 161 11/25/73 162 11/25/73 163 11/25/73 164 11/25/73 165 11/25/73 166 11/25/73 167 11/25/73 168 11/25/73 169 11/25/73 170 11/25/73 171 11/25/73 172 11/25/73 173 11/25/73 174 11/25/73 175 11/25/73 176 11/25/73 177 11/25/73 178 11/25/73 179 11/25/73 180 11/25/73 181 11/25/73 182 11/25/73 183 11/25/73 184 11/25/73 185 11/25/73 186 11/25/73 187 11/25/73 188 11/25/73 189 11/25/73 190 11/25/73 191 11/25/73 192 11/25/73 193 11/25/73 194 11/25/73 195 11/25/73 196 11/25/73 197 11/25/73 198 11/25/73 199 11/25/73 200 11/25/73 201 11/25/73 202 11/25/73 203 11/25/73 204 11/25/73 205 11/25/73 206 11/25/73 207 11/25/73 208 11/25/73 209 11/25/73 210 11/25/73 211 11/25/73 212 11/25/73 213 11/25/73 214 11/25/73 215 11/25/73 216 11/25/73 217 11/25/73 218 11/25/73 219 11/25/73 220 11/25/73 221 11/25/73 222 11/25/73 223 11/25/73 224 11/25/73 225 11/25/73 226 11/25/73 227 11/25/73 228 11/25/73 229 11/25/73 230 11/25/73 231 11/25/73 232 11/25/73 233 11/25/73 234 11/25/73 235 11/25/73 236 11/25/73 237 11/25/73 238 11/25/73 239 11/25/73 240 11/25/73 2

**THE ELECTRICITY COMMISSION OF N.S.W.**

LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 17  
ACCELERATION VIA GPC SUBROUTINE

SCALE		DATE		LAST BOX No. 17-34	
DRAWN	D.G.L.			DATE 30/4/6	
TRACED				G.A. Clessom	
CHECKED	R.M.C.			EIED per 28	
DATE 30/4/6		LD267227		C13	

[illegible]

MESSAGES

BOX NO 12-15 - RUNUP CONTINUING.

BOX NO 12-16 - DISENGAGE BARRING GEAR.

BOX NO 12-20 - ALARM FREE - (ACTUAL), BARRING GEAR NOT OPERATING, SPEED

BOX NO 12-24 - RUNUP BLOCKED UNTIL BARRING GEAR DISENGAGED.

BOX NO 12-27 - PLEASE TRIP BARRING GEAR MOTOR.

BOX NO 12-31 - PLEASE START BARRING GEAR MOTOR.

BOX NO 12-35 - RUNDOWN BLOCKED - BARRING GEAR NOT OPERATING.

BOX NO 12-42 - RUNDOWN CONTINUING.

STEP 37 - SGA (DOO 65)  
- SGB (BARRING GEAR DISENGAGED) (BOX 18-2) (STEP 37)

STEP 38 - SGA (DO 765)  
- SGB (BARRING GEAR MOTOR TRIpped) (BOX 18-5) (STEP 38)

FLAG TABLE		EXTERNAL FLAGS ONLY
NAME	DESCRIPTION	SET BY PROGRAM RESET BY PROGRAM
BG	Barring Gear Disengaged Flag	
BMT	Bar Gear Motor Tripped Flag	
BMST	Barring Gear must be Operative Flag	
MESS	Message Type Flag	
SET SW	Checks a Actions Switch (Refr. Sheet)	
ACTUAL	Value of Actual Speed	
RUNDOWN	Run down Abnormality Flag	AB200129 AB200129

LAST BOX N° 18-46

**THE ELECTRICITY COMMISSION OF N.S.W.**

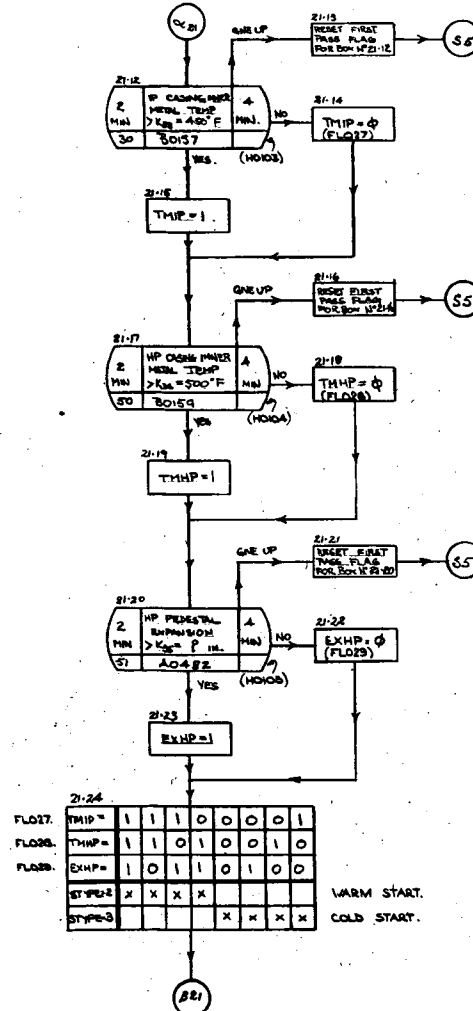
LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 18  
ACCELERATION VIA GOPC SUBROUTINES

SCALE			DATE		DATE	
DRAWN	C.W.				20/7/68	
TRACED					C.A. Glesson	
CHECKED	R.H.G.				E.E.D.	per E.J.
ASE						
DATE 30/8/68			LD267228			C/3





AMENDMENTS	1. Reinsert prior to programming.	DATE: 12-20-70	1. BOX 218 ADDL. IN REUNIFICATION	DATE: 12-23-70
			AMENDED TO SYSTEM	
			CONCERNANTS.	
			CON: R.R. CUD. J.	



K23 : H0093  
K24 : H0094  
K25 : H0095  
K26 : H0096  
K27 : H0097  
K28 : H0098  
K29 : H0099  
K30 : H0100  
K31 : H0101  
K32 : H0102

LD267231C/2

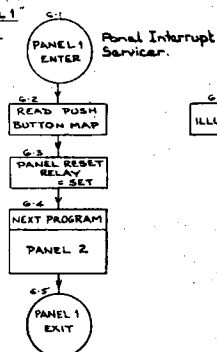
## **APPENDIX N**

**PANEL RESPONSE**

**PROGRAM FLOWCHARTS**



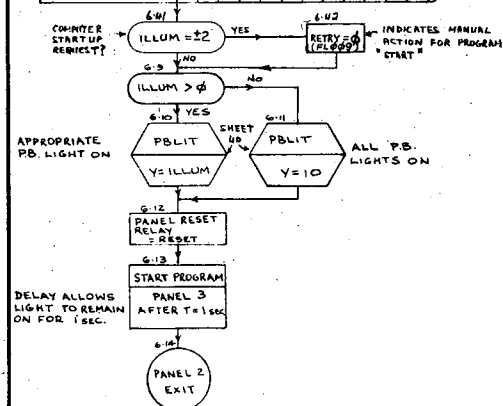
PROGRAM "PANEL 1"  
CALLED BY PANEL  
PUSH BUTTON  
INTERUPT.



PROGRAM "PANEL 2"  
CALLED BY PROGRAM  
"PANEL 1"

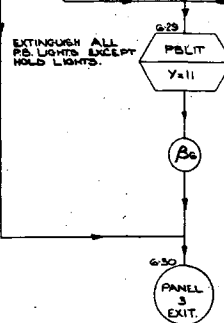
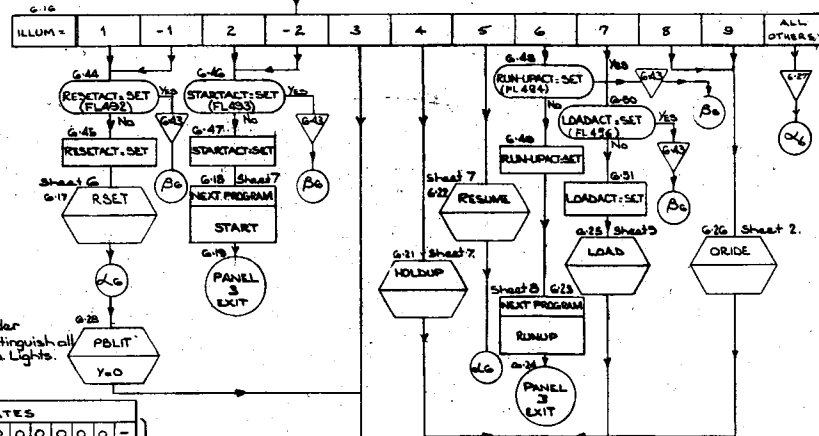
PROGRAM "PANEL 2"  
CALLED BY PROGRAM  
"PANEL 1"

INPUT DESCRIPTION	STATES										
CPU RESET RB.	X	X	0	0	0	0	0	0	0	0	-
CPU STARTUP PB.	0	-	X	X	0	0	0	0	0	0	-
RECOVERY PB.	0	0	-	X	0	0	0	0	0	0	-
HOLD PB.	0	0	0	-	X	0	0	0	0	0	-
RESUME PB.	0	0	0	0	-	X	0	0	0	0	-
START RUNUP PB.	0	0	0	0	0	-	X	0	0	0	-
START LOADING PB.	0	0	0	0	0	0	-	X	0	0	-
OVERRIDE NO PB.	0	0	0	0	0	0	0	-	X	0	-
OVERRIDE YES PB.	0	0	0	0	0	0	0	0	-	X	-
ILLUM	1	-1	2	-2	3	4	5	6	7	8	9
	ACTION										

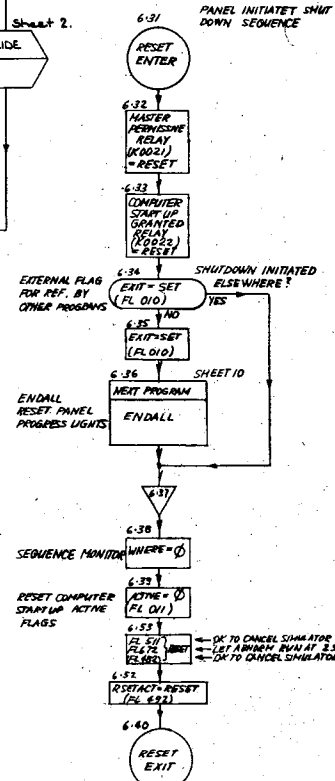


PROGRAM "PANEL 3"  
CALLED BY PROGRAM  
"PANEL 2"

Switch Table for calling related Programs.



SUBROUTINE RESET  
PANEL INITIATED SHUT  
DOWN SEQUENCE



NOTE  
FOR ALL PANEL PROGRAMS  
STEP RETURN FREQUENCY = 2 SECONDS.  
IF CPU STALLS AND SIM HAS ACTIVE TRU MUST NOT BE  
ALLOWED TO RESTART

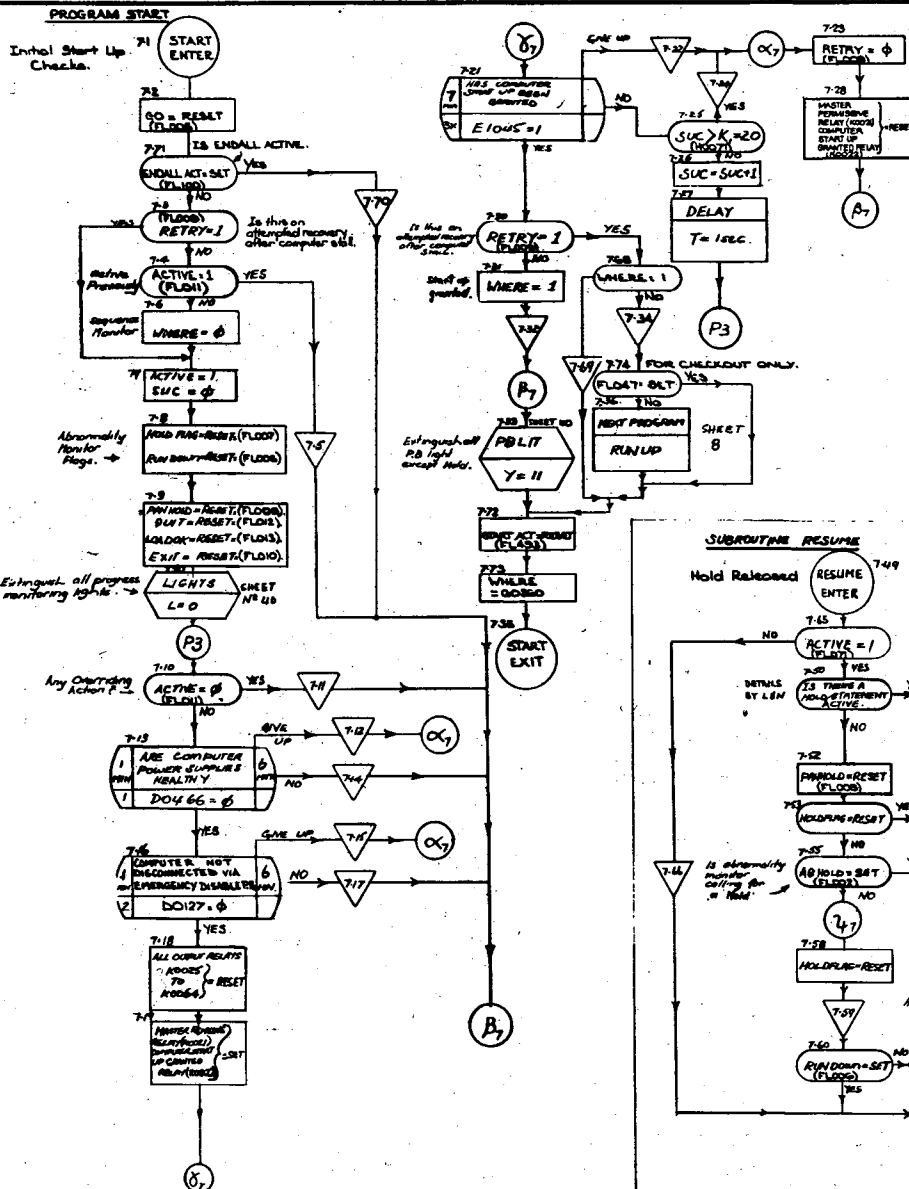
MESSAGES  
Box No. G-27 - PANEL REQUEST NOT UNDERSTOOD  
Box No. G-37 - COMPUTER RESET INITIATED.  
Box No. G-43 - TRU PANEL - INVALID REQUEST.

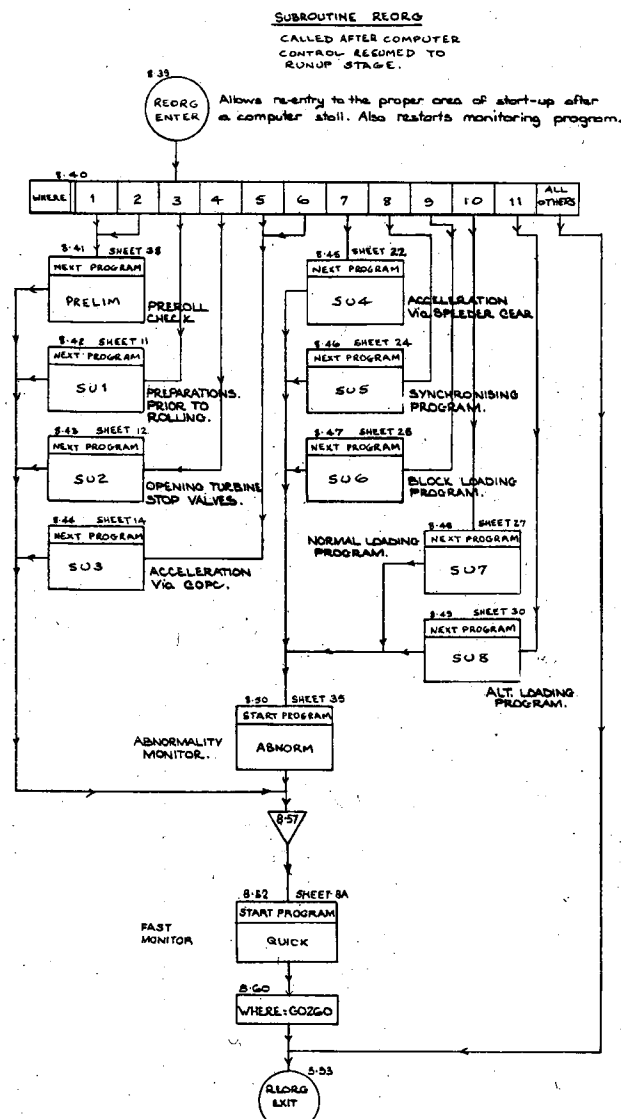
NAME	DESCRIPTION	EXTERNAL FLAG'S ONLY	SET BY PROGRAM	RESET BY PROGRAM
ILLUM	PUSH BUTTON PATTERN SWITCH		PANEL 2	PANEL 2
RETRY	ATTEMPT RECOVERY FLAG	BWG RECHECK	PANEL 2, RUNUP	
EXIT	TERMINATION REQUESTED FLAG	ANY PROGRAM	START	
WHERE	SEQUENCE MONITOR FLAG	ALL	ALL	
ACTIVE	COMPUTER STARTUP REQUESTED	START	PANEL 3, ENDALL	
RSETACT	"RSET" PROGRAM ACTIVE FLAG	PANEL 2	RSET.	
STARTACT	"START" PROGRAM ACTIVE FLAG	PANEL 2	START	
RUNUPACT	"RUNUP" PROGRAM ACTIVE	PANEL 2	RUNUP	
LOADACT	"LOAD" PROGRAM ACTIVE FLAG	PANEL 2	LOAD.	

AMENDMENTS	REVISION	DATE	BY	REASON
1.	REVISION FROM 10	10/10/64	A.S.E.	10/10/64
2.	10/10/64	10/10/64	A.S.E.	10/10/64
3.	10/10/64	10/10/64	A.S.E.	10/10/64
4.	10/10/64	10/10/64	A.S.E.	10/10/64
5.	10/10/64	10/10/64	A.S.E.	10/10/64
6.	10/10/64	10/10/64	A.S.E.	10/10/64
7.	10/10/64	10/10/64	A.S.E.	10/10/64
8.	10/10/64	10/10/64	A.S.E.	10/10/64
9.	10/10/64	10/10/64	A.S.E.	10/10/64
10.	10/10/64	10/10/64	A.S.E.	10/10/64

THE ELECTRICITY COMMISSION OF N.S.W.  
LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 6  
PANEL RESPONSE PROGRAMS AND SUBROUTINES.

SCALE	SIGNED ON ORIGINAL	DATE	LAST BOX NO. 6-53
DRAWN	DBL		DATE 30.9.69
TRACED			E/ED G.A. GLASSON
CHECKED	R.M.G.		MCS
DATE	U.S.S. 30.9.69		LD267216 C/4

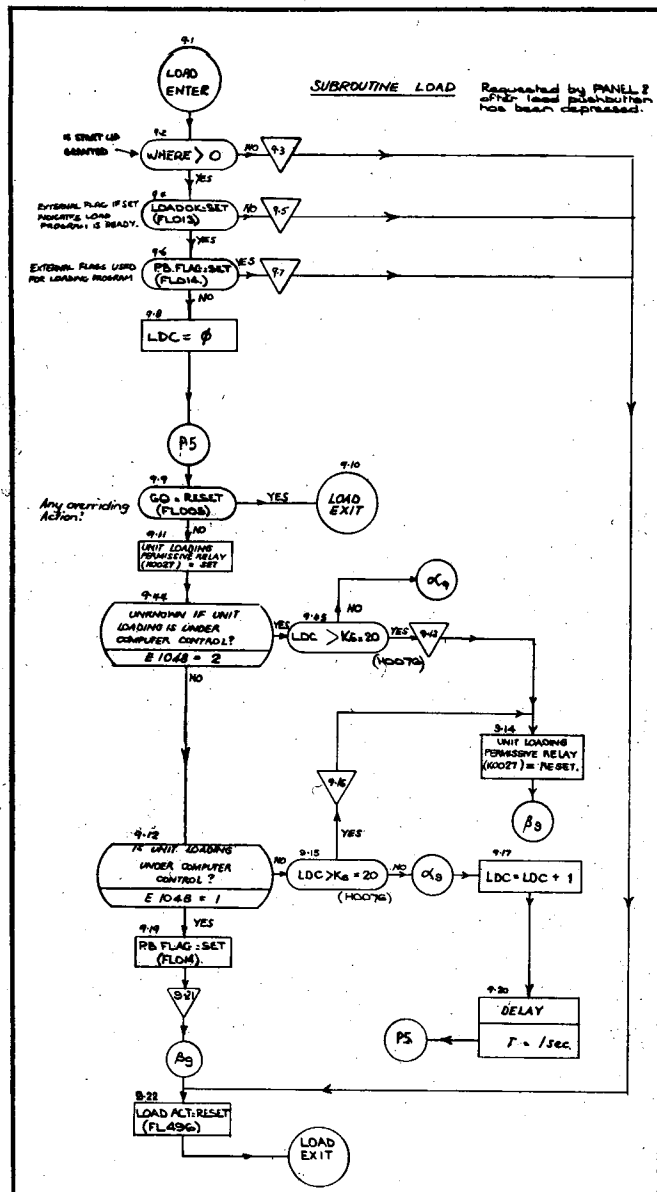




		EXTERNAL FLAGS ONLY	
NAME	DESCRIPTION	SET BY PROGRAM	RESET BY PROGRAM
WHERE	SEQUENCE MONITOR FLAG	ALL	START
GO	TURBINE CENTER PERMISSIVE FLAG	RUNUP	ENDALL, LIMBO START, BANGS.
RUC	COUNTER FOR BOM NO.3 01018.25	---	---
RETRY	ATTEMPT RECOVERY FLAG	ORNG, RECHGR	PANEL 2, RUNUP
RUNINACT	RUNUP PROGRAM ACTIVE FLAG	PANEL 2	RUNUP

LIDDELL POWER STATION  
AUTOMATIC TURBINE START FLOW CHART  
SHEET 8  
PANEL RESPONSE PROGRAM AND SUBROUTINES.

SCALE SIGNED ON ORIGINAL		DATE		DATE	
DRAWN	DDL			30-9-64	
TRACED				E/ED G A GLASSON Pm C's	
CHECKED	RMG				
ASE V.S.S. 30-9-64		LD267218 C/5			



# NOTES

## FLAG TABLE

NAME	DESCRIPTION	EXTERNAL FLAGS ONLY	
WHERE	Sequence Monitor Flag	ALL	ALL
LOADOK	Loading Program Ready Flag	SUT SUB	START
PB FLAG	Loading Requester Flag	Panel 3	SUT SUB
GO	Control Permissive Flag	Alarm	Endall, Limbo
LOADACT	Program Load Active Flag	Panel 2	Start, Bunk
LDC	Counter for Box 9.12		LOAD

## MESSAGES

9.3 - Runup Panel error - start loading requested but control not granted.  
 9.5 - Start loading requested but control not at loading stage.  
 9.7 - Start loading requested but loading in progress.  
 9.8 - Start loading request unsuccessful - unknown if unit loading under computer control.  
 9.16 - Start loading request unsuccessful - loading not under computer control.  
 9.21 - Loading Initiated.

## STEP MESSAGES

STEP 8 8GA (E1048) (D0708, D0809)

STEP 9 8GA (E1048) (D0801, D0803)  
 8GA (COMPUTER START UP GRANTED) (BOX 9.25) (STEP 9)

STEP 10 8GA (D0796)  
 8GB (UNIT SYNCHRONIZED) (BOX 9.28) (STEP 10)

AMENDMENTS	REVISION	DATE	BY	DESCRIPTION
1. APPROVED FOR PROGRAMMING	1	10/10/69	W.S.	INITIALS
2. APPROVED FOR PROGRAMMING	2	10/10/69	W.S.	INITIALS
3. APPROVED FOR PROGRAMMING	3	10/10/69	W.S.	INITIALS
4. APPROVED FOR PROGRAMMING	4	10/10/69	W.S.	INITIALS
5. APPROVED FOR PROGRAMMING	5	10/10/69	W.S.	INITIALS
6. APPROVED FOR PROGRAMMING	6	10/10/69	W.S.	INITIALS
7. APPROVED FOR PROGRAMMING	7	10/10/69	W.S.	INITIALS
8. APPROVED FOR PROGRAMMING	8	10/10/69	W.S.	INITIALS
9. APPROVED FOR PROGRAMMING	9	10/10/69	W.S.	INITIALS
10. APPROVED FOR PROGRAMMING	10	10/10/69	W.S.	INITIALS
11. APPROVED FOR PROGRAMMING	11	10/10/69	W.S.	INITIALS
12. APPROVED FOR PROGRAMMING	12	10/10/69	W.S.	INITIALS
13. APPROVED FOR PROGRAMMING	13	10/10/69	W.S.	INITIALS
14. APPROVED FOR PROGRAMMING	14	10/10/69	W.S.	INITIALS
15. APPROVED FOR PROGRAMMING	15	10/10/69	W.S.	INITIALS
16. APPROVED FOR PROGRAMMING	16	10/10/69	W.S.	INITIALS
17. APPROVED FOR PROGRAMMING	17	10/10/69	W.S.	INITIALS
18. APPROVED FOR PROGRAMMING	18	10/10/69	W.S.	INITIALS
19. APPROVED FOR PROGRAMMING	19	10/10/69	W.S.	INITIALS
20. APPROVED FOR PROGRAMMING	20	10/10/69	W.S.	INITIALS
21. APPROVED FOR PROGRAMMING	21	10/10/69	W.S.	INITIALS
22. APPROVED FOR PROGRAMMING	22	10/10/69	W.S.	INITIALS
23. APPROVED FOR PROGRAMMING	23	10/10/69	W.S.	INITIALS
24. APPROVED FOR PROGRAMMING	24	10/10/69	W.S.	INITIALS
25. APPROVED FOR PROGRAMMING	25	10/10/69	W.S.	INITIALS
26. APPROVED FOR PROGRAMMING	26	10/10/69	W.S.	INITIALS
27. APPROVED FOR PROGRAMMING	27	10/10/69	W.S.	INITIALS
28. APPROVED FOR PROGRAMMING	28	10/10/69	W.S.	INITIALS
29. APPROVED FOR PROGRAMMING	29	10/10/69	W.S.	INITIALS
30. APPROVED FOR PROGRAMMING	30	10/10/69	W.S.	INITIALS
31. APPROVED FOR PROGRAMMING	31	10/10/69	W.S.	INITIALS
32. APPROVED FOR PROGRAMMING	32	10/10/69	W.S.	INITIALS
33. APPROVED FOR PROGRAMMING	33	10/10/69	W.S.	INITIALS
34. APPROVED FOR PROGRAMMING	34	10/10/69	W.S.	INITIALS
35. APPROVED FOR PROGRAMMING	35	10/10/69	W.S.	INITIALS
36. APPROVED FOR PROGRAMMING	36	10/10/69	W.S.	INITIALS
37. APPROVED FOR PROGRAMMING	37	10/10/69	W.S.	INITIALS
38. APPROVED FOR PROGRAMMING	38	10/10/69	W.S.	INITIALS
39. APPROVED FOR PROGRAMMING	39	10/10/69	W.S.	INITIALS
40. APPROVED FOR PROGRAMMING	40	10/10/69	W.S.	INITIALS
41. APPROVED FOR PROGRAMMING	41	10/10/69	W.S.	INITIALS
42. APPROVED FOR PROGRAMMING	42	10/10/69	W.S.	INITIALS
43. APPROVED FOR PROGRAMMING	43	10/10/69	W.S.	INITIALS
44. APPROVED FOR PROGRAMMING	44	10/10/69	W.S.	INITIALS
45. APPROVED FOR PROGRAMMING	45	10/10/69	W.S.	INITIALS
46. APPROVED FOR PROGRAMMING	46	10/10/69	W.S.	INITIALS
47. APPROVED FOR PROGRAMMING	47	10/10/69	W.S.	INITIALS
48. APPROVED FOR PROGRAMMING	48	10/10/69	W.S.	INITIALS
49. APPROVED FOR PROGRAMMING	49	10/10/69	W.S.	INITIALS
50. APPROVED FOR PROGRAMMING	50	10/10/69	W.S.	INITIALS
51. APPROVED FOR PROGRAMMING	51	10/10/69	W.S.	INITIALS
52. APPROVED FOR PROGRAMMING	52	10/10/69	W.S.	INITIALS
53. APPROVED FOR PROGRAMMING	53	10/10/69	W.S.	INITIALS
54. APPROVED FOR PROGRAMMING	54	10/10/69	W.S.	INITIALS
55. APPROVED FOR PROGRAMMING	55	10/10/69	W.S.	INITIALS
56. APPROVED FOR PROGRAMMING	56	10/10/69	W.S.	INITIALS
57. APPROVED FOR PROGRAMMING	57	10/10/69	W.S.	INITIALS
58. APPROVED FOR PROGRAMMING	58	10/10/69	W.S.	INITIALS
59. APPROVED FOR PROGRAMMING	59	10/10/69	W.S.	INITIALS
60. APPROVED FOR PROGRAMMING	60	10/10/69	W.S.	INITIALS
61. APPROVED FOR PROGRAMMING	61	10/10/69	W.S.	INITIALS
62. APPROVED FOR PROGRAMMING	62	10/10/69	W.S.	INITIALS
63. APPROVED FOR PROGRAMMING	63	10/10/69	W.S.	INITIALS
64. APPROVED FOR PROGRAMMING	64	10/10/69	W.S.	INITIALS
65. APPROVED FOR PROGRAMMING	65	10/10/69	W.S.	INITIALS
66. APPROVED FOR PROGRAMMING	66	10/10/69	W.S.	INITIALS
67. APPROVED FOR PROGRAMMING	67	10/10/69	W.S.	INITIALS
68. APPROVED FOR PROGRAMMING	68	10/10/69	W.S.	INITIALS
69. APPROVED FOR PROGRAMMING	69	10/10/69	W.S.	INITIALS
70. APPROVED FOR PROGRAMMING	70	10/10/69	W.S.	INITIALS
71. APPROVED FOR PROGRAMMING	71	10/10/69	W.S.	INITIALS
72. APPROVED FOR PROGRAMMING	72	10/10/69	W.S.	INITIALS
73. APPROVED FOR PROGRAMMING	73	10/10/69	W.S.	INITIALS
74. APPROVED FOR PROGRAMMING	74	10/10/69	W.S.	INITIALS
75. APPROVED FOR PROGRAMMING	75	10/10/69	W.S.	INITIALS
76. APPROVED FOR PROGRAMMING	76	10/10/69	W.S.	INITIALS
77. APPROVED FOR PROGRAMMING	77	10/10/69	W.S.	INITIALS
78. APPROVED FOR PROGRAMMING	78	10/10/69	W.S.	INITIALS
79. APPROVED FOR PROGRAMMING	79	10/10/69	W.S.	INITIALS
80. APPROVED FOR PROGRAMMING	80	10/10/69	W.S.	INITIALS
81. APPROVED FOR PROGRAMMING	81	10/10/69	W.S.	INITIALS
82. APPROVED FOR PROGRAMMING	82	10/10/69	W.S.	INITIALS
83. APPROVED FOR PROGRAMMING	83	10/10/69	W.S.	INITIALS
84. APPROVED FOR PROGRAMMING	84	10/10/69	W.S.	INITIALS
85. APPROVED FOR PROGRAMMING	85	10/10/69	W.S.	INITIALS
86. APPROVED FOR PROGRAMMING	86	10/10/69	W.S.	INITIALS
87. APPROVED FOR PROGRAMMING	87	10/10/69	W.S.	INITIALS
88. APPROVED FOR PROGRAMMING	88	10/10/69	W.S.	INITIALS
89. APPROVED FOR PROGRAMMING	89	10/10/69	W.S.	INITIALS
90. APPROVED FOR PROGRAMMING	90	10/10/69	W.S.	INITIALS
91. APPROVED FOR PROGRAMMING	91	10/10/69	W.S.	INITIALS
92. APPROVED FOR PROGRAMMING	92	10/10/69	W.S.	INITIALS
93. APPROVED FOR PROGRAMMING	93	10/10/69	W.S.	INITIALS
94. APPROVED FOR PROGRAMMING	94	10/10/69	W.S.	INITIALS
95. APPROVED FOR PROGRAMMING	95	10/10/69	W.S.	INITIALS
96. APPROVED FOR PROGRAMMING	96	10/10/69	W.S.	INITIALS
97. APPROVED FOR PROGRAMMING	97	10/10/69	W.S.	INITIALS
98. APPROVED FOR PROGRAMMING	98	10/10/69	W.S.	INITIALS
99. APPROVED FOR PROGRAMMING	99	10/10/69	W.S.	INITIALS
100. APPROVED FOR PROGRAMMING	100	10/10/69	W.S.	INITIALS

THE ELECTRICITY COMMISSION OF N.S.W.

LIDDELL POWER STATION  
 AUTOMATIC TURBINE START FLOW CHART  
 SHEET 9  
 PANEL RESPONSE PROGRAM AND SUBROUTINES

SCALE	SIGNED ON ORIGINAL	DATE	DATE
DRAWN	N.S.		30.9.69
TRACED			
CHECKED	N.M.G.		
A.S.E.			
DATE	30.9.69	LD267219	C/6

## **APPENDIX O**

### **EXAMPLE OF CONTROL PROGRAM LISTING**

1	C PROGRAM SU2 -- OPENS TURBINE STOP VALVES -- CALLED BY PROGRAM SU1	SU200000
2	C UPDATED 1/19/72 GRP	SU200100
3	PROGRAM SU2	SU200200
4	CLASS SPL	SU200300
5	INTEGER WHERE,SVSW,FAIL,COUNT,BBCT,TVCT,ACCT,PRCT,SPCT,	SU200400
6	*SVCT,CPCT,CHKLOCK,BUFF,CHKANLOG	SU200500
7	DIMENSION NSF(7)	SU200600
8	COMAREA/COMAREA1/H0079,H0080,H0081,H0082,H0083,H0084,H0085,	SU200700
9	* H0086,H0087	SU200800
10	COMAREA/COMAREA3/ WHERE,SVSW,FAIL,COUNT, BBCT,TVCT,ACCT,	SU200900
11	* PRCT,SPCT,SVCT,CPCT,BASE	SU201000
12	EQUIVALENCE (NSF(1),BBCT),(NSF(2),TVCT),(NSF(3),ACCT),	SU201100
13	* (NSF(4),PRCT),(NSF(5),SPCT),(NSF(6),SVCT),(NSF(7),CPCT)	SU201200
14	DPCOMAREA/DPCOM4/ B1001,B1001R,B1002R,B0156,B0160,B0161	SU201300
15	C FLO45 = SVC0NF, QA0K SET IF QA#28 IS SATISFIED AND NO LONGER IN	SU201400
16	C PROGRESS BEFORE GOING TO SU3.	SU201500
17	FLO58 = .FALSE.	SU201600
18	BUFF = 8	SU201700
19	WHERE = 4	SU201800
20	GO260 = WHERE	SU201900
21	123 CHECKPOINT 1	SU202000
22	C	SU202100
23	IF(.NOT.FLO05) GO TO 999	SU202200
24	IF(FLO07)GO TO 126	SU202300
25	IF (.NOT.FL500) GO TO 1210	SU202400
26	126 CALL DELAY(60)	SU202500
27	GO TO 123	SU202600
28	C 128 ARE INPUT SCAN FREQUENCIES OK	SU202700
29	1210 IF(CHKANLOG(B1001).LT.5) GO TO 1212	SU202800
30	INDEX = 534	SU202900
31	GO TO 9	SU203000
32	1212 BASE = B1001	SU203100
33	GO264 = BASE	SU203200
34	II = 0	SU203300
35	IF(B0156.LT.H0079)II=1	SU203400
36	INDEX = 536	SU203500
37	CALL QA(18,1,B0156,II,0,120,300,2,0)	SU203600

38		G0 T0 (1216,9,1214),II	SU203700
39	1214	INDEX = 535	SU203800
40		G0 T0 9	SU203900
41	1216	II=0	SU204000
42		IF(E0160,LT,H0080)II=1	SU204100
43		INDEX = 538	SU204200
44		CALL QA(19,1,B0160,II,0,120,300,2,0)	SU204300
45	C		SU204400
46		G0 T0 (1219,9,1217),II	SU204500
47	1217	INDEX = 537	SU204600
48		G0 T0 9	SU204700
49	1219	II=0	SU204800
50		IF(E1071)II=1	SU204900
51		INDEX = 540	SU205000
52		CALL QA(20,0,E1071,II,0,120,300,2,0)	SU205100
53		G0 T0 (1222,9,1220),II	SU205200
54	1220	INDEX = 539	SU205300
55		G0 T0 9	SU205400
56	1222	II=0	SU205500
57		IF(D0783)II=1	SU205600
58		INDEX = 548	SU205700
59		CALL QA(21,0,D0783,II,0,120,300,2,0)	SU205800
60		G0 T0 (1225,9,1223),II	SU205900
61	1223	INDEX = 547	SU206000
62	9	CALL MESS(INDEX,BUFF)	SU206100
63		CALL HOLD	SU206200
64	C	NSF(1)-NSF(7) =BBCT,TVCT,ACCT,PPCT,SPCT,SVCT,CPCT	SU206300
65	1225	SVSW =1	SU206400
66		FAIL = 0	SU206500
67		CBUNT = 0	SU206600
68		FLO45 = FALSE	SU206700
69		D0 8 J=1,7	SU206800
70	8	NSF(J)=0	SU206900
71	1226	CHECKPOINT 2	SU207000
72	C		SU207100
73	12260	IF(.N0T,FL005) G0 T0 999	SU207200
74		IF(FL007)SVSW = 0	SU207300
75	1230	II=0	SU207400

76	IF(B0161.GT.H0081)II=1	SU207500
77	K=1	SU207600
78	INDEX = 542	SU207700
79	CALL QA(22,1,B0161,II,0,3,6,2,0)	SU207800
80	GO TO (1235,7,1232),II	SU207900
81	1232 INDEX = 541	SU208000
82	C*****	SU208100
83	C THE NEXT 11 LINES ARE STANDARD LOGIC FOR REQUESTING A PERIODIC MESSAGE	SU208200
84	7 IF(NSF(K).NE.0) GO TO 6	SU208300
85	EXECUTE 9	SU208400
86	GO TO 5	SU208500
87	6 IF(NSF(K).NE.32)GO TO 5	SU208600
88	NSF(K)=0	SU208700
89	C	SU208800
90	GO TO 3	SU208900
91	5 NSF(K)=NSF(K)+1	SU209000
92	3 IF(K.EQ.4) GO TO 4	SU209100
93	IF(K.GT.5)GO TO 4	SU209200
94	SVSW =0	SU209300
95	4 GO TO(1238,1250,131,136,1321,1334,1341),K	SU209400
96	C*****	SU209500
97	1235 NSF(1) = 0	SU209600
98	C	SU209700
99	1238 II=0	SU209800
100	IF(E1071)II=1	SU209900
101	K=2	SU210000
102	INDEX = 543	SU210100
103	CALL QA(23,0,E1071,II,0,3,6,2,0)	SU210200
104	GO TO (1245,1241,7),II	SU210300
105	1241 IF(CBUNT .GT.0)GO TO 1242	SU210400
106	INDEX = 545	SU210500
107	GO TO 7	SU210600
108	1242 INDEX = 544	SU210700
109	EXECUTE 9	SU210800
110	1320 K0036 = .TRUE.	SU210900
111	K0037 = .TRUE.	SU211000
112	K0038 = .TRUE.	SU211100
113	K0039 = .TRUE.	SU211200

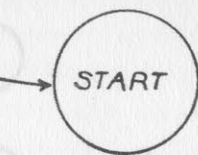


## **APPENDIX P**

### **COMPUTER CONTROLLED TURBINE**

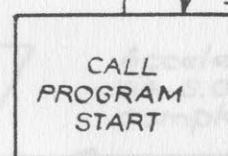
#### **RUN-UP AND LOADING PROGRAM FLOW**

Called when  
computer start-up  
P.B. pressed.

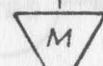


# THIS PROGRAM :-

1. CHECKS IF COMPUTER POWER SUPPLIES ARE HEALTHY.
2. OPENS ALL CONTROL OUTPUT RELAYS.
3. CLOSES MASTER PERMISSIVE RELAY.
4. CLOSES START-UP GRANTED RELAY.



Computer  
start-up  
granted.

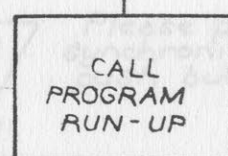


"Start  
Run-up"  
push button.

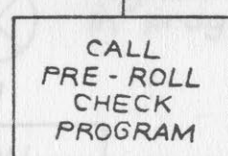
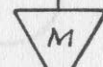


# THIS PROGRAM :-

1. CHECKS IF PRESSURE BEFORE T.S.V. O.K.
2. INCREASES SCAN FREQUENCY OF CONTROL INPUTS.
3. CLOSES TURBINE PERMISSIVE RELAY.
4. CHECKS IF G.O.P.C. ISOL. VALVE SELECTED TO COMPUTER.
5. CHECKS IF G.O.P.C. CONTROL VALVE SELECTED TO COMPUTER.  
(i.e. G.O.P.C. CONTROL VALVE SELECTED TO AUTO AND  
G.O.P.C. SPEED SET POINT SELECTED TO COMPUTER.)
6. CHECKS IF SPEEDER GEAR MOTOR SELECTED TO COMPUTER.
7. CHECKS IF T.S.V. ARE UNDER COMPUTER CONTROL.
8. INITIATES A MONITORING PROGRAM 'QUICK'



Run-up  
Initiated.

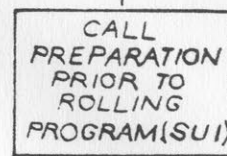


Permissives O.K.  
progress monitoring  
light ON.

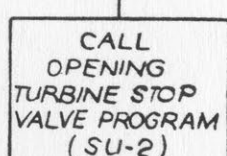


THE PURPOSE OF THIS PROGRAM IS TO ENSURE  
THAT ESSENTIAL PRESTART REQUIREMENTS STILL  
EXSIST IMMEDIATELY PRIOR TO THE COMPUTER  
INITIATING ANY CONTROL ACTION.

Pre-roll  
check O.K.  
Run-up  
proceeding.



Computer has  
run speeder  
gear to 2940 r.p.m.  
position.



Ready to  
Run-up  
monitoring light  
comes ON



# THIS PROGRAM :-

1. CHECKS IF T.S.V.'S ARE CLOSED.
2. RECHECKS IF G.O.P.C. ISOL. AND  
CONTROL VALVE SELECTED TO COMPUTER.
3. RUNS S.G. TO MIN. POSITION.
4. OPENS G.O.P.C. ISOL. AND CONTROL  
VALVES.
5. RUNS S.G. TO 2940 R.P.M. POSITION.

# BEFORE OPENING T.S.V. THIS PROGRAM

1. CHECKS IF H.P. VALVE CHEST STEAM/  
METAL DIFF. TEMPERATURE < 100°F
2. CHECKS IF GOV. OIL PRESS. < 31 p.s.i.
3. CHECKS IF THROTTLE VALVES ARE  
CLOSED
4. CHECKS IF T.S.V. SETTING GEAR IS  
CLOSED
5. CHECKS IF BEARING OIL PRESSURE  
> 15 p.s.i.

AMENDMENTS

LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE  
RUNUP AND LOADING  
CONTROL PROGRAM FLOW

DRAWN

CHECKED

SHT

1

LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE  
RUNUP AND LOADING  
CONTROL PROGRAM FLOW

SCALE

DATE

D

AMDT



Computer has opened all T.S.Vs. Run-up proceeding.

$\alpha$

M

DETERMINE LOADING RATES (SU-3)

DETERMINES THE TYPE OF TURBINE START. (HOT RECOVERY, HOT, WARM OR COLD) AND THE START TYPE IS USED FOR THE SELECTION OF ACCELERATION AND LOADING PARAMETERS.

ACCELERATION VIA G.O.R.C. PROGRAM (SU-3)

DURING ACCELERATION VIA G.O.R.C. COMPUTER CHECKS.

1. IF TEMP. SOAKING OF TURBINE IS REQUIRED (IF SO THE DURATION OF THE SOAKING PERIOD.)
2. IF IN CRITICAL SPEED RANGE
3. BARRING GEAR OPERATION IF SPEED < 300 R.P.M.

HAS GOVERNOR TAKEN CONTROL OF TURBINE SPEED

No

Run-up in progress light ON.

ACCELERATE TURBINE VIA SPEEDER GEAR (SU-4)

$\lambda$

IS SPEED < 2940 R.P.M

No

HAS SPEED REACHED 3070 R.P.M

No

Yes

3

EXIT

3

$\times$

Run-up completed.

M

Acceleration via S.G. completed.

ARE SYNCHRONISING PREREQUISITES SATISFIED.

No

M

Operator requested to take appropriate action.

Yes

$\times$

Ready to synchronise. Monitoring light comes ON

M

Please press synchroniser push button.

IS SYNCHRONISER OPERATING

No

Yes

$\times$

Synchronising in progress.

CALL SYNCHRONISER PROGRAM (SU-5)

IS UNIT SYNCHRONISED

No

If hardware synchronised has failed to synchronise unit after 5 mins. operator requested to trip synchroniser.

M

$\lambda$

Yes

$\times$

Unit synchronised.

$\beta$

AMENDMENTS

LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE  
RUNUP AND LOADING  
CONTROL PROGRAM FLOW

DRAWN

CHECKED

SHT

2

DATE

SCALE

LIDDELL POWER STATION  
COMPUTER CONTROLLED TURBINE  
RUNUP AND LOADING  
CONTROL PROGRAM FLOW

AMDT

D





APPENDIX Q

DIGITAL INPUTS USED

IN CONTROL FUNCTION

# DIGITAL INPUTS

INPUT No.	DESCRIPTION	INPUT No.	DESCRIPTION
D0025	MILL A CB CLOSED	D0333	STATOR WTR GAS-STR HP HIGH
D0026	MILL B CB "	D0334	STATOR WATER MAKEUP TANK LEVEL ABNORM
D0027	MILL C CB "	D0338	STATOR WTR STRAINER BLOCKED
D0028	MILL D CB "	D0339	STATOR WATER FLOW LOW
D0029	MILL E CB "	D0340	STATOR WATER H.L.P. FLOW HIGH
D0030	MILL F CB "	D0346	CHW HP PRESS ABNORMAL
D0031	MILL G CB "	D0357	CHW-THEM COOLING STEAM S.B.Y. PUMP UNAV.
D0032	MILL H CB "	D0464	FP A S.B.Y. OIL PUMP UNAV.
D0062	FP A MOTOR CB CLOSED	D0466	COMPUTER POWER SUPPLIES FAILED
D0065	BARRING GEAR DISENGAGED	D0568	EFT A READY
D0079	RAC ON AUTO	D0569	EFT B READY
D0080	RAC ON START-UP MODE	D0583	CHW THRU PUMPS ON
D0081	RAC ON MANUAL MODE	D0606	STATOR WTR COOLER TEMP CONTRL VLV ON AUTO
D0084	RAC ON DES MODE	D0607	HP COOLER TEMP CONTRL VLV ON AUTO
D0085	RAC ON REMOTE MODE	D0676	CONDENSER VIBRATION ESTABLISHED
D0097	SFFT EXH TO CONDENSER-VALVE CLSD	D0677	" " " " " "
D0126	FP B MOTOR CB CLOSED	D0702	LP SPRAY FEED SYSTEM CONTRL VLV ON AUTO
D0210	SFFT OIL-RED. CHW. ALARM ON	D0705	LP SPRAY REC SYSTEM CONTRL VLV ON AUTO
D0215	SFFT POWER OIL PRESSURE LOW	D0719	SFF GLAND SEALING CP ISOL. VLV OPEN
D0217	SFFT S.B.Y. FWR OIL PMP UNAV.	D0747	COND PUMP A READY
D0218	SFFT REG OIL PRESS LOW	D0748	COND PUMP B READY
D0219	SFFT AC REG OIL PMP UNAV.	D0751	TURB OIL PMP A READY
D0220	SFFT DC REG OIL PMP UNAV OR OVERLOADED	D0752	TURB OIL PMP B READY
D0226	FP S.B.Y. GLAND SEALING WTR PMP UNAV.	D0753	STATOR WATER PMP A READY
D0229	SFF GAUGE PANELS GENERAL ALARM ON	D0754	STATOR WATER PMP B READY
D0233	FP B S.B.Y. OIL PUMP UNAV.	D0755	DIST WATER PUMP A READY
D0250	S.B.Y. OIL PMP UNAVAIL	D0756	DIST WATER PUMP B READY
D0252	POWER OIL PRESS LOW	D0761	DIST WATER PUMPS IN SERVICE
D0254	TURB OIL TANK LEVEL LOW	D0765	TURBINES BARRING GEAR (HIGH SPEED) OPERATING
D0255	TURB AC S.B.Y. LUBE PUMP UNAVAIL	D0768	SPEEDER GEAR SET TO CPU
D0256	TURB DC S.B.Y. LUBE PUMP UNAV OR OVERLOADED	D0769	COFC CONTRL VALVE SET TO CPU
D0259	REG OIL PRESS LOW	D0770	COFC ISOL VALVE SET TO CPU
D0262	AC S.B.Y. SEAL OIL PUMP UNAVAIL	D0771	COFC CONTRL VALVE OPEN
D0263	DC S.B.Y. SEAL OIL PUMP UNAV OR OVERLOADED	D0773	COFC CONTRL VALVE CLOSED
D0264	SEAL OIL PRESS LOW	D0776	COFC ISOLATING VALVE OPEN
D0265	SEAL ANNULUS PRESS ABNORMAL	D0777	COFC ISOLATING VALVE CLOSED
D0268	OIL DEFOAM TANK LEVEL ABNORM.	D0778	SPEEDER GEAR MIN POSN
D0271	LP SPRAY BOOSTER PUMP UNAV.	D0779	SPEEDER GEAR MAX POSN
D0272	LP SPRAY S.B.Y. PUMP UNAV OR OVERLOADED	D0780	SPEEDER GEAR 2940 POSN
D0275	REG GLAND STEAM PRESS ABNORMAL	D0781	FEEDBILLS LIFTED
D0276	GLAND STEAM EXH PRESS LOW	D0782	ALL TURB STOP VALVES OPEN
D0277	EXHAUSTER VACUUM LOW	D0783	TRV SETTING GEAR CLOSED
D0286	CONDENSATE CONDUCTIVITY HI	D0784	HP VLV TRIP GEAR RESET
D0320	PUMP FOREBAY WATER LEVEL LOW	D0785	PRESS X TV BELOW 35 PSIG
D0326	DIST WATER S.B.Y. PUMP UNAV.	D0790	AVR ON AUTO
D0328	DIST WATER MAKEUP FLOW HIGH	D0792	VACUUM BELOW 27 IN
D0329	DIST WATER TANK LEVEL ABNORM	D0793	SYNCH KEY INSERTED
D0331	STATOR WATER S.B.Y. PUMP UNAV	D0794	SYNCHRONISER ACTIVE
D0332	GAS LEAKAGE HIGH	D0796	UNIT SYNCHRONISED
D0801	CPU START GRANTED	D0800	CPU START NOT GRANTED
D0802	TURBINE SPEED LIMITER OPERATING		
D0803	CPU RESET GRANTED		
D0804	TURB ON CPU CONTROL		
D0805	TURB OFF CPU CONTROL		
D0806	TURB STOP VALVES ON CPU CONTROL		
D0807	TURB STOP VALVES OFF CPU CONTROL		
D0808	LOADING ON CPU CONTRL		
D0809	LOADING OFF CPU CONTRL		

APPENDIX R  
DIGITAL OUTPUTS  
USED IN CONTROL FUNCTION

DIGITAL OUTPUTS

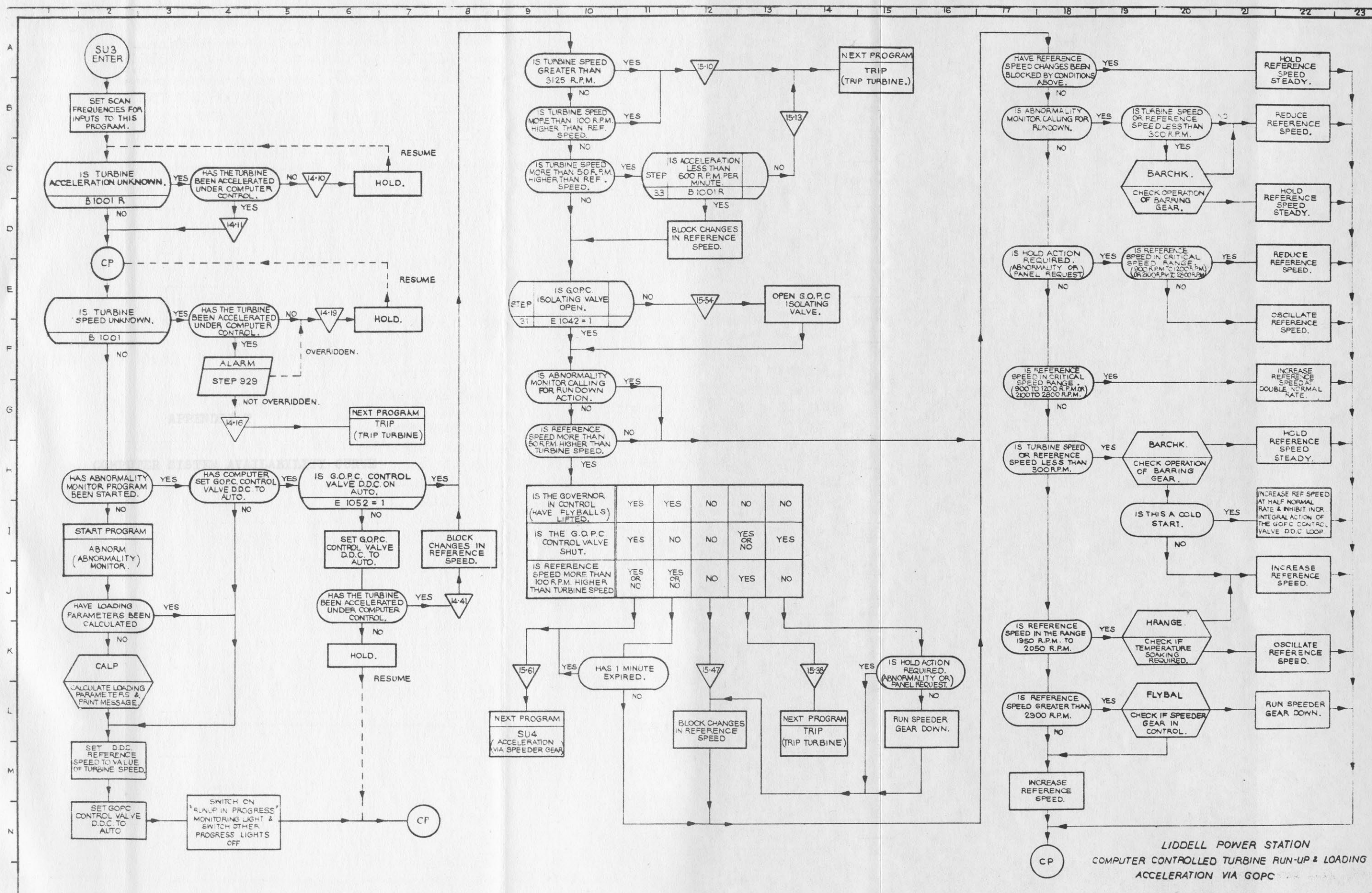
RELAY NO.	DESCRIPTION
K0021	MASTER PERMISSIVE
K0022	COMP. START UP GRANTED
K0025	BOILER CONTROL PERMISSIVE
K0026	TURBINE CONTROL PERMISSIVE
K0027	UNIT LOADING PERMISSIVE
K0029	GOPC CONTROL VALVE OPEN
K0030	GOPC CONTROL VALVE CLOSE
K0031	GOPC ISOLATING VALVE OPEN
K0032	GOPC ISOLATING VALVE CLOSE
K0034	TURBINE TRIP GEAR (OIL) VALVE NO. 1 RESET
K0035	TURBINE TRIP GEAR (OIL) VALVE NO. 2 RESET
K0036	TURBINE TRIP (OIL)
K0037	TURBINE TRIP (OIL)
K0038	TURBINE TRIP (OIL)
K0039	TURBINE TRIP (OIL)
K0040	TURBINE ELECT. TRIP
K0041	TURBINE ELECT. TRIP
K0042	TURBINE ELECT. TRIP
K0043	TURBINE ELECT. TRIP
K0045	REQUIRED OUTPUT SETTER LOWER

RELAY NO.	DESCRIPTION
K0046	REQUIRED OUTPUT SETTER RAISE
K0047	STEAM PRESSURE SET POINT LOWER
K0048	STEAM PRESSURE SET POINT RAISE
K0049	TURBINE STOP VALVE A CLOSE
K0050	TURBINE STOP VALVE A OPEN
K0051	TURBINE STOP VALVE B CLOSE
K0052	TURBINE STOP VALVE B OPEN
K0053	TURBINE STOP VALVE C CLOSE
K0054	TURBINE STOP VALVE C OPEN
K0055	TURBINE STOP VALVE D CLOSE
K0056	TURBINE STOP VALVES D OPEN
K0057	TURBINE STOP VALVES SLOW SPEED
K0058	TURBINE STOP VALVES FAST SPEED
K0059	EMERGENCY DC RELAY OIL PUMP OFF
K0060	EMERGENCY DC RELAY OIL PUMP ON
K0061	FUEL OIL PRESSURE SET POINT LOWER
K0062	FUEL OIL PRESSURE SET POINT RAISE
K0063	SPEEDER GEAR LOWER
K0064	SPEEDER GEAR RAISE



## APPENDIX S

COMPUTER CONTROLLED TURBINE  
RUN-UP AND LOADING SAMPLE  
TRAINING FLOWCHART



APPENDIX T

COMPUTER SYSTEM AVAILABILITY CURVE



# LIDDELL No 2 COMPUTER SYSTEM AVAILABILITY CURVE

