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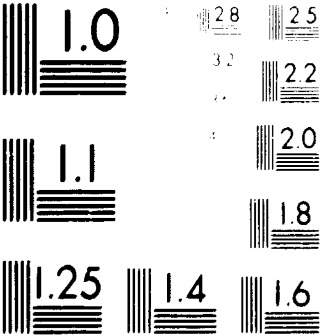
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CHINA

Terminal report*

Prepared for the Government of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Martti O. Nevalainen,
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United Nations Industrial Development Organization
Vienna

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EXPLANATORY NOTES

NPP	=	Nuclear Power Plant
NPPTS	=	Nuclear Power Plant Training Simulator
PWR	=	Pressurized Water Reactor
P	=	Proportional (controller)
PI	=	Proportional Integral (controller)
PID	=	Proportional Integral Derivative (controller)
MIS	=	Management Information System
OR	=	Operations Research
UNDP	=	United Nations Development Programme
UNIDO	=	United Nations Industrial Development Organization
KW	=	Kilo Words
MB	=	Mega Bytes
CRT	=	Cathode Ray Tube
CPU	=	Central Processing Unit
A/D	=	Analog to Digital
D/A	=	Digital to Analog
FPP	=	Floating Point Processor
MOS	=	Metal Oxide Semiconductor
ECC	=	Error Correction Code
IC	=	Initial Condition

ABSTRACT

As part of the United Nations Development Programme (UNDP) project DP/CPR/79/021/11-08/31.9.B, an expert was sent by the executing agency the United Nations Industrial Development Organization (UNIDO) to the Acheng Relay Works, Acheng Power Station Equipment Automation Design & Research Institute (called hereafter the "Institute") in the Heilongjiang Province the People's Republic of China (called hereafter "China"). The co-operating agency was the First Ministery of Machine Building Industry in China.

The purpose of the mission was to develop mathematical modeling, dynamic simulation and automation techniques for large steam power stations.

The mission was carried out from 30 November 1982 to 1 March 1983. It was the second mission under this project. The first mission was carried out by Mr. P. Soininen from 14 October 1981 to 14 January 1982.

During the second mission the expert delivered a series of lectures to the specialists of the local Institute and to the attending representatives of other institutes, universities and organizations.

The lectures covered techniques of building linear and nonlinear fossile and nuclear power plant simulation models. Included in the lectures were also power plant training simulators, instrumentation and control systems as well as some other topics.

The expert also guided model development work on the Institute's digital computer. A nonlinear model of a fossile fuelled 200 MW drum type boiler power plant was developed, tested and verified. A linear simulation model of a similar plant was also programmed but not tested.

The Institute has an important duty in designing and testing of process components and control systems of the new 600 MW fossile units and nuclear power plants by means of digital simulation.

The nonlinear model developed during this mission can be used for analysis of power plant transients, dimensioning its components, developing and tuning of control systems and in training in basic principles of plant operation. Any existing or future drum type boiler plant can be simulated with the model. After slight modifications also once-through boiler plants can be simulated.

The lectures submitted, the literature provided and the experience gained during the practical work facilitate building of new simulation models and conducting the required research work at the Institute. However, its computing facilities are not adequate for such work and they must be upgraded or entirely renewed. Proposals are presented for both alternatives in this report.

In the advent of building large 600 MW fossile power plants and nuclear generating stations in China the training of operators, plant availability and safety become essential questions. By using simulators improvement can be achieved in all these areas. Therefore, full-scope training simulators have to be built in near future for both of the mentioned plant types.

Upon the request of the co-operating agency in China, UNIDO has taken an active role in promoting the development of fossile power plant simulation and automation technology in China. It is the opinion of the expert that this course has to be continued and the help has to be widened also to the field of nuclear power plant automation and simulation to make sure that the necessary training and research facilities for the 600 MW fossile power plants and nuclear plants can be built in due time to ascertain the availability, economy and safety of the energy production in China.

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INTRODUCTION

To improve the living standard of its more than 1 billion population the People's Republic of China (hereafter called China) has set herself a new economic goal to quadruple the annual value of industrial and agricultural production by the end of this century. Wether this goal is reached or not depends to a large extent on the development of energy resources.

In some regions a chronic energy shortage has acted as a brake on development. For instance in some areas of the Heilongjiang Province factories operate only three or four days a week due to shortage of electricity and the whole province lacks 1.3 million MWhours of electricity annually (China Daily, Feb. 2, 1983).

To cope with the problem of energy shortage on-land and offshore oil fields will be developed, abundant hydropower resources will be utilized to the maximum extent, large fossil fuelled power stations will be built in provinces with large coal reserves and nuclear power stations in regions lacking conventional energy resources will be built as well (China Reconstructs, 32, 1983, 1).

Coal accounts for 70 per cent of China's current energy sources and 200 to 300 MW coal-fired generating stations serve as the backbone of power grids in the country. Low competence level of operators has caused accidents at these plants and great losses in the economy. Furthermore, the rate of energy gained per ton of fuel consumed is still very low compared with that of developed countries.

Modern power plant automation and simulators can be used to improve the availability, safety and economy of power production and hence, should be fully explcited to ease the energy shortage in China. Therefore, United Nations Development Programme (UNDP) with its executing agency United Nations Industrial Development Organization (UNIDO) has taken an active role and established the project DP/CPR/70/021/11-08/31.9.B in order to promote the utilization of these concepts in China where the co-operating agency is the First Ministry of the Machine Building Industry.

Under this project two experts have been sent by UNIDO for 3 months mission the the Acheng Relay Works in the Heilongjiang Province which is one of those provinces bothered by the chronic energy shortage

The Acheng Relay Works is specilized in research and production of complete relay protection and automatic control systems for thermal and hydropower stations, for eletric networks and other applications. These equipment have been installed to about one thousand power plants in China and abroad. The factory operates two research institutes with a simulation laboratory equipped with analog and digital simulation facilities.

The UNIDO experts were attached to one of the institutes called the Acheng Power Station Equipment Automation Design & Research Institute (hereafter referred to as the "Institute"). The factory is working under the co-operating agency.

The first mission described in /1/ was carried out by Mr P. Soininen from 14 October 1981 to 14 January 1982. The second mission, which is the subject of this final report, was carried out from 30.11.1982 to 01.03.1983. The objectives, as defined by UNIDO, were slightly modified as the result of discussions with the local representatives. For instance some aspects of nuclear power were added to the programme.

The final Work Plan was carried out according to the agreed timetable except that some rescheduling was necessary at the end due to the computer failure during the practical work.

All the agreed objectives were reached except that due to the unreliability of the computing facility there was no time left for the experimenting with the developed nonlinear simulation model.

RECOMMENDATIONS

1 Third expert should be sent to the Institute for three months to give lectures and guidance in nuclear reactor theory, nuclear power plant (NPP) simulation, automation and control.

2 The computer system at the Institute should be upgraded or completely renewed to facilitate efficient research and development work utilizing real-time simulation techniques.

3 A basic principle nuclear power plant training simulator (NPPTS) should be built and located in the Institute to train the necessary staff for building and operating nuclear power plants in Heilongjiang Province and elsewhere in China. The simulator would also facilitate carrying out the required research work in the NPP field at the Institute. It is proposed that the simulator is implemented on the new computer system outlined in this report thereby automatically satisfying the recommendation presented under the previous item.

4 Trips to conventional and nuclear power plants and training centres in foreign countries should be arranged for the specialists of the Institute.

5 The simulator know-how already existing at the Institute should be used in the ongoing planning of the training centre project for 300 MW plants and to supervise the Chinese interest in this project. E.g. the control room should be delivered by a Chinese enterprise and the Institute's specialists should participate in the project to cut down the hard currency requirements and to gain experience. A highly qualified and neutral consultant should be used in specifying the request for tenders and, later on, in evaluation of the tenders.

6 The building of the 600 MW fossile power plant training simulator should be started immediately to have it available for the initial training of the operators.

7 The preparations for building a full scope nuclear power plant training simulator should be started.

8 Literature on nuclear reactor theory and nuclear power plants in general should be made available to the Institute and some prominent periodicals on the area of simulation and control should be ordered for it.

9 The level of the English language should be enhanced among the simulation specialists of the Institute to facilitate participation in international conferences and in simulator implementation projects in the deliverer's project organization in foreign countries.

10 The responsibilities of the modeling specialists in the Institute should be divided such that competence on all important areas of power plant simulation and control could be gradually built up.

11 Programming and documentation standards should be developed. For this end a software quality control engineer should be nominated.

12 A 3 month expert mission dealing with the enterprise management using digital computers should be arranged. The objective is to promote the application of mathematical methods and computer based information systems in China.

13 The possibilites of UNDP/UNIDO assistance in the financing the implementation of the above recommendations should be studied.

14 The simulation models developed during this mission should be further developed and experiments should be conducted with them according to the lines proposed in this report.

I OBJECTIVES OF THE MISSION

A. Job description

The purpose of the project in broad terms has been described in the first page of the eclosed Job Description in Appendix 1.

The Duties during this mission are also described in Appendix 1 and presented below with small changes in the wording to reflect better the expert's actual understanding of the Job Description:

1. Providing technical guidance and training for the local personnel in the following fields related to the automation of steam power plants:

   a) computer controlling techniques for coal-fired units and control philosophy for a 600 MW drum type boiler and turbine plant.

   b) detection technique for turbine rotor thermal stress and flame in boiler chamber

   c) microcomputer applications.

2. Providing technical guidance and training in the area of building and utilizing digital computer based simulators for coal-fired power plants and, in particular, on the following:

   a) building mathematical models for dynamic simulation of large coal fired power plant processes in order to analyse transients and to dimension the power plant components

   b) use of power plant simulators to design, test and optimize plant control systems

   c) thermal power plant operator training simulators (simulator types, standards, utilization areas, role of simulators in training of power plant operators, functional and technical requirements of a modern full-scope training simulator)

   d) simulator languages for digital computers.

B. Work Plan

In addition to the above objectives as defined by UNIDO the activities carried out by Mr. Soininen, the results obtained and the recommendations presented in his final report /1/ were observed when deciding on the final work plan for the mission at hand. The highest priority, however, was attached to the requirements and views presented by the local representatives. As a result the final Work Plan enclosed in Appendix 2 was agreed upon. All the requirements presented by the local representatives were accepted and, therefore, the contents and timing of the Work Plan fully reflect the wishes of the hosts.

The main emphasis in the Work Plan was put on the lecturing. About 2 weeks were, in addition, allocated for practical work consisting of the development of a nonlinear dynamic simulation model for a large power plant, model verification and experimenting with it.

Items 1b) and 1c) in Section A above were dropped from the Work Plan and on item 2d) literature was only provided.

Because the decision to build nuclear power in China was announced in December 1982 the local representatives were interested to include nuclear power plant aspects in items 2, 3 and 4 of the Work Plan. Item 6 was added to provide some introduction to the simulation and modeling of nuclear power plants especially the reactor part.

Considerable interest also existed in the area of enterprise management using digital computers. Therefore, this subject was also added in part 8 of the Work Plan.

II ACTIVITIES CARRIED OUT

A. Lectures

General

The lectures were carried out according to the Work Plan of Appendix 2. In all, 35 lectures 2.5 hours each were given from 8.30 to 11.30 with half an hour's break in the middle. The afternoons were reserved for discussions and for preparing next day's lectures.

Modeling and simulation

This subject was treated under items 1, 6 and 7 dealing with nonlinear and linear drum type boiler plant modeling as well as a PWR typ NPP modeling respectively. Some aspects of control system simulation were covered under items 3 and 8.1 as well.

The scope of power plant dynamics simulation must usually be limited to an approximate mathematical model which accurately portrays only the necessary interactions of interest.

Simulation of a large, complex boiler-turbine system can be performed either with an empirical or a basic physics modeling approach.

In the empirical approach the process is modeled through approximation of responses by simple lags and delay functions. As the details within the process are largely ignored and only the inputs and outputs retained this is sometimes called a "black box approach". Such models have the advantage of simplicity but the disadvantage of difficulty in relating model parameters to physical plant parameters. The determination of time constants for boilers of various types and sizes is a considerable problem and the models are normally only applicable for units already in operation. These models have mainly been used for subsystem control studies and grid frequency stability studies.

The basic physics modeling approach involves a thorough understanding of the physical processes of the power plant. The following basic equations are used in modeling the plant components:

- conservation of mass
- conservation of energy
- conservation of momentum.

After having derived the mathematical equations the final formulation depends on the intended application of the model.

The equations obtained are nonlinear partial differential and algebraic equations. An essential step is to convert the continuous space dimension into discrete steps by defining finite volume elements and the equations for their inlet and outlet conditions.

The other step which was virtually mandatory before the advent of digital computers was to convert the nonlinear equations into linear small perturbation equations about a suitable steady state operating point. Although the linearization approach still is very useful a fully nonlinear approach is quite feasible using digital computers.

In studying the dynamic properties of a large steam power plant both small and large power changes are of interest. For small load changes it is usually sufficient to use linear models. However, different model coefficients may be required for different operating points which can make the use of linar models laborous.

Based on the above reasoning and on the fact that the available computing capacity at the Institute is fairly limited it was decided to give lectures on both the linear and nonlinear power plant modeling to facilitate the application of both methods in the reser work at the Institute.

In both cases the basic physics ing approach was strictly adhered to and a further goal was to aim at an algorithmic form of models whereby different power plant designs could be simulated by simply introducing new plant construction parameters readily available from the plant documentation. References /2/ and /3/ represent such approaches and the lectures on nonlinear and linear power plant modeling respectively were largely based on these references.

Nonlinear real-time simulation model

This subject was treated in great detail because the intention was to implement this model on the Institute's computer during the practical work period (item 5 in the Work Plan).

One important reason for selecting the model package described in /2/ as the subject of lectures and the practical work was that, according to the expert's knowledge, it is the best freely available nonlinear dynamic simulation package fully meeting the objectives indicated in the Job Description. In addition it also meets the criteria put forward in the preceeding paragraph. According to reference /2/ the previous version of this model has been accepted by the utilities and vendors of power plants in USA as the standard for all future modeling efforts.

During the lectures all the model equations were derived in full detail for each power plant component included in the model and the computer implementation of the model was described. Finally some possible directions for further development of the model and its application possibilities were described. In this model Euler method is used in numerical integration, but also the Runge-Kutta method, explicit and implicit methods as well as predict correct methods were introduced.

Further details on the model and its implementation on the Institute's computer are given in Section II B below.

Linar real-time simulation model

Also the linear dynamic simulation model (item 6 in Appendix 2) for a large drum type boiler plant was described in great detail facilitating the building of the model based on the lecture notes provided. The necessary mathematical background was included consisting of matrix and vector calculus as well as fundamentals of linear algebra.

Following the basic physics modeling approach all the nonlinear equations describing the main plant components were derived in detail in the following form:

$$(1) \qquad \underline{f}\,(\dot{\underline{v}},\ \underline{v},\ \underline{u}) = \underline{0}$$

$$(2) \qquad \underline{g}\,(\underline{y},\ \underline{v},\ \underline{u}) = \underline{0}$$

The components of vectors $\underline{f}$ and $\underline{g}$ are nonlinear functions of variables $\underline{v}$ and their derivatives $\dot{\underline{v}}$, the process input variables $\underline{u}$ and the output variables $\underline{y}$ as indicated by equations (1) and (2) above.

The linearization of equations (1) and (2) was performed for each subprocess separately leading to a set of linearized equations of the following form:

$$(3) \qquad \underline{E}\,\dot{\underline{v}} + \underline{F}\,\underline{v} + \underline{G}\,\underline{u} = \underline{0}$$

$$(4) \qquad \underline{P}\,\underline{y} + \underline{Q}\,\underline{v} + \underline{R}\,\underline{u} = \underline{0},$$

where the perturbed variables around the steady state have been denoted as the original variables. The coefficient matrices in (3) and (4) were derived in detail and the reduction to the state-space form of eqs (5) and (6) was described based on the matrix pseudo inverse method presented in /3/.

$$(5) \qquad \dot{\underline{x}} = \underline{A}\,\underline{x} + \underline{B}\,\underline{u}$$

$$(6) \qquad \underline{y} = \underline{C}\,\underline{x} + \underline{D}\,\underline{u}$$

Also, a suitable control system for the simulated plant process was introduced and the computer implementation of the model was described. Further details of the linear model are given in Section IIc below.

Nuclear power plant simulation

There were neither previous experience nor any literature available, concerning the nuclear power plant field, at the Institute. Therefore, a brief introduction on the nuclear reactor theory was given starting from the basic interactions between neutrons and the nuclei, introducing the neutron transport equation, group diffusion equation and reactivity feedback effects. The point reactor model and its linearized form for simulation purposes were derived.

The simulation of a PWR primary circuit was described based on /4/ and an educational linear small basic principle NPP simulator was introduced based on /5/.

Power plant training simulators

This subject was treated under item 2 in the Work Plan based on the expert's experience gained at Nokia Electronics in Finland in building power plant training simulators, and on the large amount of literature provided in this subject.

The lecture notes and the provided literature should give a fairly complete picture of various types of training simulators, benefits obtained by using training simulators and of their various utilization areas. Both training and other utilization possibilities were described. A short summary of advantages in using training simulators is given in Appendix 3.

The requirements for the hardware, software, functions and fidelity of a full-scope state-of-the-art training simulator were presented as well as the prerequisites for successful implementation of large training simulator projects.

No attempt was made to give a thorough description of the mathematical models of a full-scope training simulator but only the basic outline of the model programs and some special modeling techniques were described.

Other subjects

In part 3 of the lectures the main control systems of a large drum type boiler plant were presented based on the experience gained in Finland as documented in /6/. In addition some special methods for improved control performance were included.

Closely related with this subject is part 8.1 of the lectures where P, PI and PID control of the most common dynamic control loop elements were discussed. This item was mainly based on /7/. Procedures for adjusting standard controllers optimally and digital control algorithms for their simulation were presented.

Item 4 of the lectures deals with the automation of steam power plants. Typical present day intrumentation and control system solutions were introduced for conventional and nuclear power plants and future trends were descussed.

A special lecture was given on the use of digital computers in enterprise management. In addition to the regular audience the management of the Acheng Relay Works was attending this lecture. During one lecture only a few basic ideas could be introduced like MIS and OR. The presentation was based on the expert's previous lectures /8/ held in the Technical University of Helsinki and elsewhere.

One special lecture, not shown in the Work Plan, concerned the specification of the requirements for a modern simulation research facility for the Institute. It also included an option for upgrading of the existing computer facility. The proposals are summarized in Appendix 4 and in Section IV D, respectively.

In addition to the formal lectures there were numerous discussions after the lectures and in the evenings and trips were made, normally Sundays, to the near-by industry as listed in Appendix 5.

B. Practical work

General

Twelve days were allocated for the practical work. The main goal was to implement the nonlinear simulation model described in part 1 of the lectures.

The idea was to proceed according to the list of tasks as shown in part 5 of the Work Plan. It soon appeared, however, that the tasks could not be performed in the planned time because of the limitations of the computing facilities available and its extremely poor reliability. A complete account of all the problems met during this short period of practical work is given in Appendix 6. The main disadvantage was that a lot of time was waisted and all the effort had to be concentrated in order to get the programs ready. Even though one additional week was allocated for the practical work the programs could only be implemented and verified but there was no time left for experimenting with the model. Besides, most of the flexibility of the original software package was lost due to the limitations of the computing facilities.

Good spirit, high competence and hard work of the key persons made the implementation of the model package possible in the short time available in spite of all the difficulties encountered.

Nonlinear model

In Fig. 1 a simplified process diagram of the simulated drum type boiler plant is shown. The submodels included in the implemented program package are shown in Table I. In addition, a drum level controller program is included.

Only those subprocesses are included which are important in determining the plant dynamic responses, therefore, e.g. the condenser and the feedwater heaters have been disregarded but they can be easily added later.

All submodels are based on basic physics principles except for the secondary superheater and the economiser model which are based on empirical correlations.

The flow diagram of the dynamic model data and the interactions between the submodels are shown in Fig. 2 and the software layout of the machine time simulation package is shown in Fig. 3.

Validation of the nonlinear model

The validation of the model package was performed by running the same tests as in /2/. The tests included 1 steady state, 2 closed loop and 3 open loop transient tests. The results are shown in Appendix 7 and further discussed in Section III B below.

Experimenting with the nonlinear model

Plans were made for experimenting with the model but due to the lack of time these experiments could not be performed. It is, however, proposed that these experiments are performed after the mission by the Institute staff (c.f. Section IV A).

Linear Model

Even though not included in the original Work Plan some spare time was used for programming a linear machine-time simulation model as well. The simulated plant process diagram is shown in Fig. 4. The principal flow chart of the simulation program is shown in Fig. 5. The model is especially designed for experimental purposes taking into account the limitations of the available computing facilities. It also includes the simulation of the controllers shown in Fig. 4. The program needs still debugging and the model has to be verified but it can be performed after this mission. The linear model is in some respects more complete than the nonlinear model (e.g. economizer, downcomer, waterwalls, 2 spray valves, 3 superheaters and the reheater) but e.g. the gas path and the combustion are not simulated in the same detail. On the Institute's computer the linear model will probably run much faster than real-time.

C. Provided literature

A great share of the provided literature was from the area of simulation and control of conventional and nuclear power plants. Another main topic was training simulators. The amount of various papers and publications is too numerous to be listed in detail in this report. Therefore, only the books and some of the most prominent reports are listed in Appendix 8.

D. Factory visits

A list of all visits performed during the mission is given in Appendix 5. All factories visited were manufacturing high quality products but computers were not utilized in any of them even though considerable interest was displayed in all the factories towards such applications. It was emphasized in many places that the methods described in the expert's lectures are general in nature and can be as well applied in other industries and not only in the power plant field.

III RESULTS OBTAINED AND THEIR UTILIZATION

A. Lectures and literature

Perhaps the most important result under this heading is that the ambitious lecture program shown in Appendix 2 was realized. It included all the subjects proposed by the local representatives. In addition about 500 pages of highly concentrated lecture notes were distributed after copying and about 75 kg of relevant literature was submitted.

The aspects in developing linear and nonlinear simulation models of the major power plant components were treated in great detail based on the basic physics modeling approach and algorithmic technique using the plant construction data. These methods make the models virtually independent of the power plant and different plant designs and sizes can be readily simulated. For a research and development type of work this feature of the model is highly desirable.

The lectures submitted and the material provided give the ability for the local specialists to build both linear and nonlinear models based on the above principles. Linearized models can be used for small transients and the model execution requires only small amount of computing capacity while the nonlinear models can simulate any transients but require more computing capacity. Both types of applications are needed in the research work.

All the main control systems of the drum type boiler plant and optimal controller parameter setting were covered. This facilitates design of and experimenting with various control concepts using the simulators.

In near future China will need training simulators for large conventional and nuclear power plants. The lectures given and the literature provided will be for great help for the decision making in this complex and important area.

In the advent of building commercial nuclear power in China it is essential to have enough specialists with a sound background to build and operate such plants. One of the most efficient ways to familiarize with the basic principles of a nuclear power plant operation is by the aid of small educational simulators. Therefore, the lectures and material provided from this are are quite important even though clearly insufficient. However, they should make it possible to build a small educational linear basic principle nuclear power plant simulation model at the Institute.

8. Practical work

Nonlinear model

One important objective in building the nonlinear model was to gain experience in building large simulation models in general using digital computers. This includes deriving the model equations using the basic physics and algorithmic technique, design of simulation software, programming the submodels based on modular principles, individual testing of the submodels, their integration and testing and, as the last stage, the verification of the model. Valuable experience in all these phases was obtained during the practical work.

The implemented nonlinear simulation model package has the following desirable features:

- Except for two submodules all the modeling is based on basic physics approach.
- The package is general allowing any existing or proposed drum type fossil-fuelled power plant to be simulated by the model.
- After slight modifications the model can also be applied for simulation of once through boiler plants.
- The package is modular and implemented in high level language (Fortran IV) allowing easy modification, insertion and deletion of component submodels.
- The package is well documented e.g. complete program listings are freely available.
- The models have been verified with the field test data and this data is readily available in the literature /2/ and /9/.
- The package is interactive including software support routines for input of parameters to control the simulation run, manipulation of control variables during run, and output of results in printed table or printed plot format.

The implemented software package reserves 21 KW (16 bit/w) of core space and exceeds the computing capacity of the Institute's computer with respect to the real-time simulation. Hence, it takes 1.25 minutes of machine time to simulate one minute of real time. This precludes all attempts to perform real time simulation with this model - or indeed with any more complex model - while using the computing facilities available at the Institute. This is a serious limitation for efficient and meaningful research work.

Even if lot of the original flexibility of the model package has been lost due to the limited computer facilities it can ba used e.g. for the following purposes:

- analysis of big and small transients at the power plant
- dimensioning of power plant components
- developing, testing and tuning of power plant control systems implemented by software
- training in basic principles of power plant operation
- verifying the correct operation of linearized models.

Results from the verification tests are shown in Appendix 7. According to the results the steady state accuracy for all measured variables except for the gross power output and the secondary superheater heat transfer rate is better than 3 % and in most cases better than 2 %. The reasons for the poor accuracy of the two variables mentioned above have been explained in /2/. In the closed loop transient tests the results were almost identical with those presented in /2/ and in the open loop tests the direction of changes was the same but the rate of changes was different probably due to the different initial condition.

The short time available for running the tests did not allow to wait sufficiently long to reach a good steady state as the starting point of the actual transients. The unavailability of the puncher output unit prevented all attempts to create new initial conditions. Therefore, e.g. the open loop tests had to be initiated from different steady state condition than in /2/.

Linear model

The amount of numerical calculations to derive the linearized form of equations (3) and (4) as well as to establish the model matrices in the state-space form (5), (6) is very extensive. Therefore, it is advisable to let the computer make as much as possible of this work. Such programs exist in the literature /3/, /10/ and they were provided for the Institute. They make the linear power plant models virtually independent on the process under consideration and any existing or new plant designs can be easily simulated around different steady state conditions.

The linear machine-time simulation model programmed during the mission, after it has been properly tested and verified, can be used e.g. for the following purposes:

- design, testing and tuning of regulators for steady state control
- design of plant process itself
- training in basic principles of power plant operation.

Due to the linear modeling approach only small power changes around the steady state can be simulated by one specific model. A control system as indicated in Fig. 4. is included in the linear model program.

IV FINDINGS AND RECOMMENDATIONS

A. Experimenting with the nonlinear model

The short time available did not allow any experimenting to be performed with the nonlinear model. It is proposed that following experiments would be made with the model:

a) Study the model behaviour by making the transient tests described in pp. 84-116 of /2/.

b) Try various integration time steps and find out the biggest timestep which does not cause numerical problems yet.

c) Experiment with the relevant control concepts introduced in part 3 of the lecture notes.

d) In connection with point c above try the tuning methods described in sections 4.4.7-4.4.9 of the lecture notes.

e) Implement the control systems described in Fig. 6 using the standard controller subroutines introduced in section 5.5 of the lecture notes.

f) For convenient use of the Ziegler-Nichols tuning method implement the support routine described in section 5.5 of lecture notes.

g) Modify the physical plant construction parameters in the common area according to the Chinese 200, 300 and 600 MW plant and experiment with these models.

B. Further development of the nonlinear model

a) Derive basic physics models also for the economiser and the secondary superheater using the same principle as in the primary superheater model.

b) Remodel the downcomer/waterwall system to account for variations in flow rate and fluid conditions. This refinement is necessary if the model is extensively used in open loop research.

c) Add a reheater model to provide a more realistic simulation in transients and better data for power plant output analysis. The model would be analogous with the primary superheater model.

d) Fit the combustion efficiency curve with the Chinese coal. Additional modules are needed to calculate masses of combustion products and the actual heating value of the fuel if the model is to be used in pollution research.

e) As pointed out in /2/ several subsystem models are described in the literature which can be used to improve the simulation accuracy of the model. Descriptions of these submodels were included in the literature left in the Institute /11/, /12/, /13/, /14/.

C. Linear model

a) Test and validate the linear model program written during the mission by using plant measurement data given in /3/.

b) Implement the program for the drum model building based on plant construction data /4/ and the program for the linearized model reduction to the state space from /8/ on the Institute's computer.

c) Implement the linearized Cromby ≠ 2 model and verify it against the existing nonlinear model and the available plant measurement data.

d) Implement a linear model for the Chinese 200, 300 and 600 MW power plants.

D. The computer system

Table II shows the main features of the Institute's computer system. Based on the experience gained and the problems encountered during the practical work it is the expert's opinion that the computer system should be upgraded or completely renewed to facilitate the carrying out of the research tasks given to the Institute.

The expert's proposal for a new computing facility is shown in Fig. 9. It should be provided unless six first of the upgrading items listed below can be implemented:

1. Make available the Fortran real-time features to facilitate building of real-time simulators. In such a case the control desk at the simulation laboratory shown in Fig. 7 and the nonlinear model developed during this mission could be used. The control desk has had no use so far.

   There is also a vast amount of good quality analog control units shown in Fig. 8 at the simulation laboratory. These equipment could be connected to the real-time simulator and used in the research work.

2. The 300 l/minute lineprinter in the simulation laboratory should be connected to the computer. This would save a lot of time and effort in program development and add flexibility in using the computer.

3. The core memory should be replaced by semiconductor memory to increase the computing speed.

4. To speed up the program development work display terminals should replace the paper tape. This would require the availability of the computer's time-sharing features.

5. To facilitate the storage of large amounts of programs and data large disks e.g. 2x75 MB should be added.

6. The reliability and availability of the computer hardware should be improved by intensified preventive maintenance and by providing spare parts for the most essential components like the memory modules.

7. The semigraphic colour CRT at the control desk shown in Fig. 7 cannot be used presently. If it would be available real time simulators based on data display on the CRT could be implemented. Useful experience could be obtained and research work conducted in the area of man-machine communication.

E. Nuclear power

a) China has decided to build nuclear power plants. A lot of specialists with sound background are needed to build and operate such plants. A nuclear power plant will probably also be built in near future in the Heilongjian province. The Acheng Relay Works would in such case certainly have a major role in implementing the instrumentation and control systems of the plant. At the present time there is practically no experience from the nuclear power plant area at the simulation Institute.

It is, therefore, proposed that a third expert would work for 3 months at the Institute. The main emphasis should be put on lecturing on the nuclear reactor theory, simulation and control of PWR nuclear power plants especially the nuclear reactor. During the practical work dynamic simulation models on the reactor and simplified models on the entire plant should be developed. The expert should, in addition, be completely familiar with the models and principles described in /2/ and /3/ to be able to give further guidance also on these areas if so required.

b) In order to speed up the building up of the necessary staff it is proposed that a basic principles NPP training simulator is purchased and located at the Institute.

c) Literature on the nuclear reactor theory and control of nuclear power plants should be provided to the Institute.

F. Full-scope training simulators

In near future China will need full-scope training simulators for large fossil and nuclear power plants. Building such simulators involves great potential risks ranging from less than satisfactory performance of the simulator to a complete disaster with several years delays and big economical losses. Therefore, it is proposed that an experienced simulator manufacturer would be involved from the beginning in such projects.

In this connection at least three different simulator projects should be considered:

a) Training centre for 300 MW coal fired unit.

UNDP has decided to support with 600 000 USD this project while the Government of China will finance the rest. The project is handled in the Ministry of Water Resources and Power. The Chinese Government is also responsible on the contracting and execution of the project with the help of UNIDO. An international tendering will be arranged not in too distant future.

In the expert's opinion this project should not be executed purely on a turn key basis but the possibilities of the Chinese enterprises to make subdelivieries and to participate in the project should be considered. For instance, it is mandatory to have a Chinese control room in the simulator. The control room could be delivered e.g. by the Acheng Relay Works. Also the expertice and know-how built up at the simulation Institute should be utilized in the planning of the project, to supervise the Chinese interests and later on in the implementation to cut down the costs.

To avoid costly mistakes a highly qualified and neutral consultant should be available assisting UNIDO in specifying the requests for tender and to evaluate the tenders.

b) Training simulator for 600 MW coal-fired power plants

If the initial training of the operators for these plants should be given by the training simulator the building of this simulator should be immediately started since the first unit should be operational in 1986.

In discussions with the Chinese counterparts it appeared that a similar solution should be found for the financing problem as that one discussed under item a) above. In other words UNIDO should give some financing support, China is taking care of one part of the tasks herself and using hard currency for financing the rest. After executing the project a) above the Chinese deliveries and participation could be relatively increased in this project.

c) Training simulator for PWR nuclear power plants

This should be handled in analogy with the fossile power plant simulators. After having built the basic principle simulator mentioned under item E.b) above a full scope NPP training simulator project should be established according to the same lines as in case Fb) above.

The ultimate goal should be the ability of China to build simulators selfsufficiently based on the experience gained and technology transferred during these initial projects. One candidate for building the simulators for China in future is the Acheng Relay Works.

G. The simulation Institute

a) The Institute at the present time is too isolated and is not able to follow the development of the simulation and control field in the world. It is proposed that the following periodicals would be ordered to the Institute: "Simulation", "Control Engineering" and "Nuclear Engineering International" to alleviate this problem.

b) Lectures in the English language should be given regularly to the Institute staff to facilitate better communication in this language and participation in international conferences and simulator projects abroad in future.

c) To cope with the duties of designing and testing the control systems for the new 600 MW fossil plant and the nuclear power plants with the aid of simulator, specialists for the following fields are needed:

- boiler simulation
- nuclear reactor simulation
- turbine and feedwater system simulation
- electrical systems simulation
- automatics, safety and protection system simulation (plant logics)
- control system simulation
- software design and development
- simulator hardware

d) Emphasis should be put on establishing programming and documentation standards. A software quality control engineer should be nominated for this purpose. A preliminary proposal for a documentation standard was provided by the expert.

H. Operations Research methods

There was a considerable interest in the industry towards the application of OR-methods which are not in general use in China yet. In a typical case a 6 % increase in profit can be achieved by applying these methods. It is a sufficiently large subject to deserve alone a separate 3 months mission to introduce the multitude of mathematical methods, applications and information system structures available. The main emphasis should be put on mathematical programming methods especially linear programming and on the simulation of discrete processes. Practical applications in real-life problems should also have a great emphasis.

I. UNDP/UNIDO Assistance

The recommendations put forward in chapters D to H above require funds for their implementation. The possibilities of UNDP/ UNIDO assistance in the financing should be investigated. A summary of the candidate projects identified during the mission is given below in the order of priority:

1. Providing an expert for 3 months to give technical guidance and training in the area of nuclear reactor theory, NPP simulation, automation and control.

2. Upgrading or entirely renewing the digital computer facility of the Institute.

3. Purchasing a basic principle NPP training simulator to the Institute. The simulator should be implemented on the computer system shown in Fig. 9, thereby automatically satisfying also the previous point. The purchase price of the complete simulator would be about 700 KUSD.

4. Building a full-scope training simulator for 600 MW fossile power plants. The total purchase price would be 4-7 MUSD.

5 Building a full-scope NPP training simulator. The total purchase price would be 6-10 MUSD.

6. Providing literature on nuclear reactor theory and NPPs in general and ordering periodicals on the field of simulation and control.

7. Organizing trips to power plants and simulation training centres in foreign countries for the Institute's specialists.

8. Arranging a three months expert mission on the area of digital computers in enterprise management.

Acknowledgement

The expert would like to express his gratitude to UNIDO, UNDP, the First Ministry of Machine Building Industry of the People's Republic of China, Acheng Relay Works and Nokia Electronics for the co-operation and help which made this interesting mission possible.

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ISA Transactions, 9, 1970 (4):pp 309-15.

TABLE I Simulated subsystems and submodels of the program package

Subsystem		Submodel name
- Feedwater valve	FWV	BFP
- Boiler feed pump	BFP	
- Economiser	ECO	DWN
- Downcomers	DWN	
- Waterwalls	WWL	DRUM
- Steam drum	DRM	
- Primary superheater	PSO	SUPER
- Secondary superheater	SSO	SECOND
- Attemperator spray	AT1	
- Throttle valves	THR	THROTTLE
- High pressure turbine	HPT	TURBINE
- Low pressure turbine	LPT	
- Combustion furnace	CFURN	CFURN
- Primary superheater furnace	PSFURN	PSFURN
- Secondary superheater furnace	SSFURN	SSFURN

TABLE II Main features of the Institute's computer system

CPU	; DJS-154 (Chinese)
Main memory (core)	; 32 kw (=max.), 16 bit/w
Peripherals	
- magnetic drum	; 2x64 kw (moving head)
- paper tape read/write	
- console typewriter	; 6 lines/min
I/O interface	
- multiplexer	
- A/D converters	; 500 serial lines 128 parallel lines
- D/A converters	; 45 serial lines 45 parallel lines
CPU speed	
- Fixed point add time	; 4.8 μs
- Fixed point multiplic. time	; 16.2 μs
- Floating point add time	; 33 μs
System software	
- Real- time operating system	
- Library subroutines	
- Auxiliary programs	
- Hardware diagnostics program	
- Assembly language	
- Time-sharing Basic	
- Fortran IV	
- Algol 60	

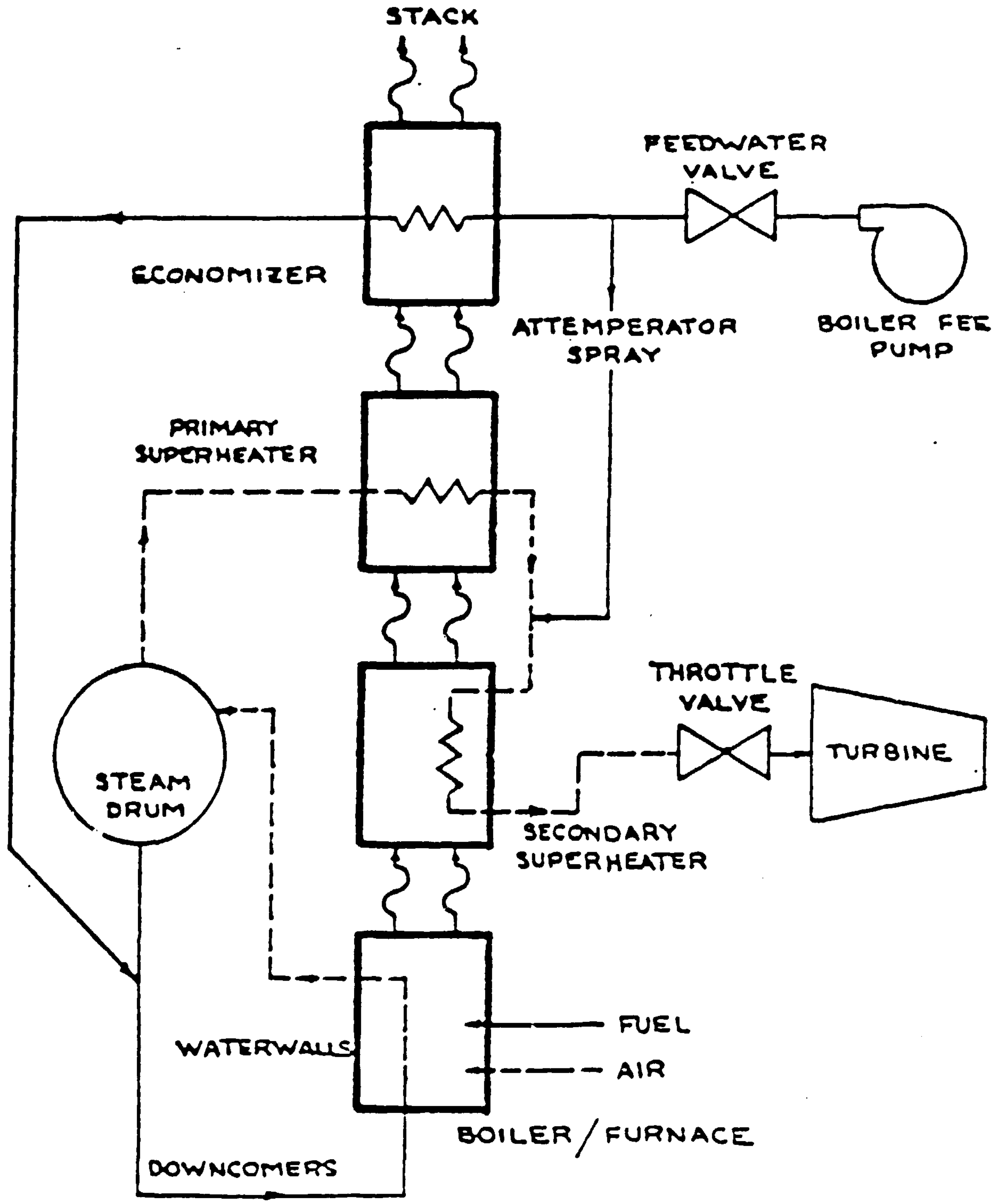


Fig. 1 Simplified process diagram from the simulated plant (from /2/)

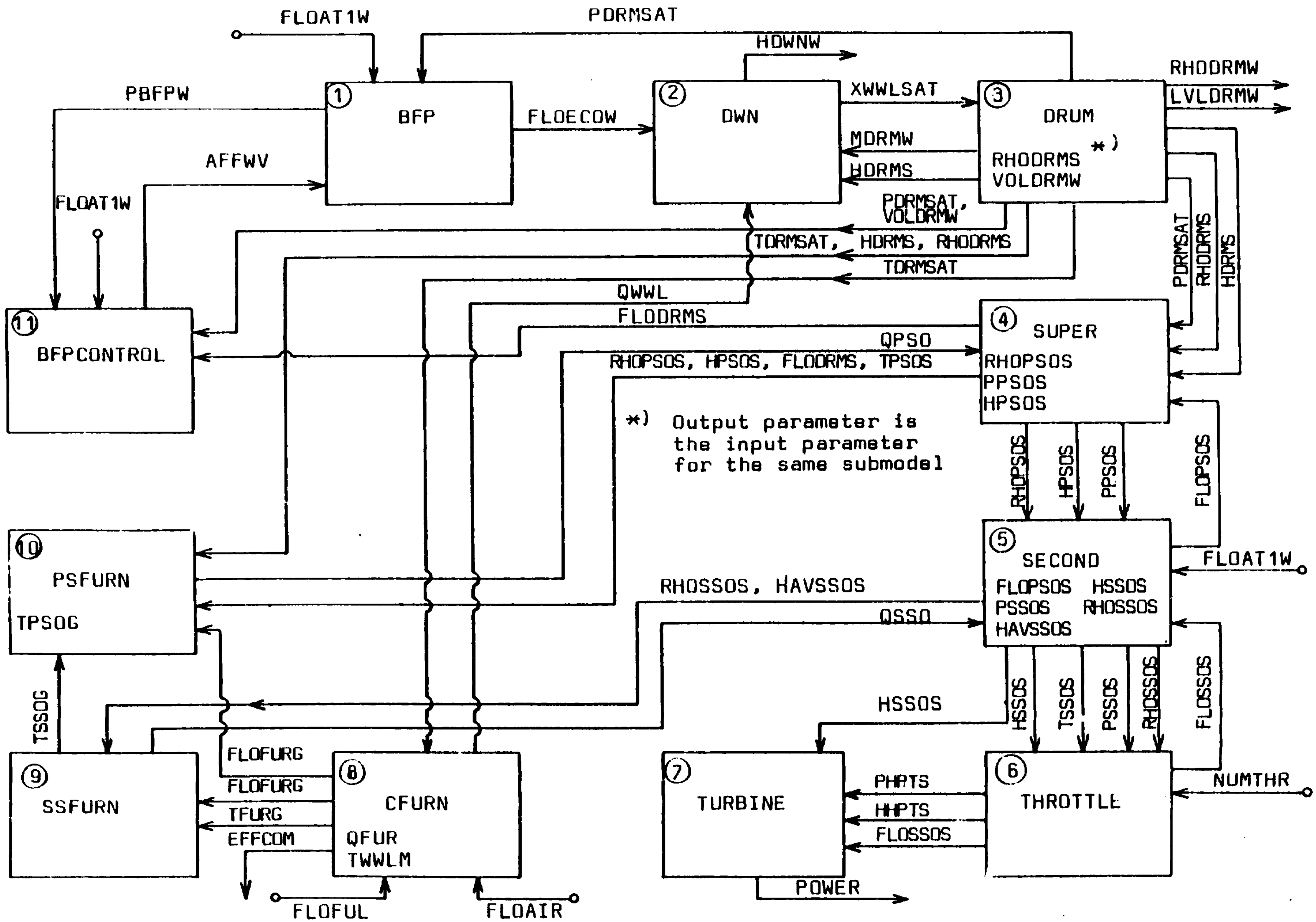
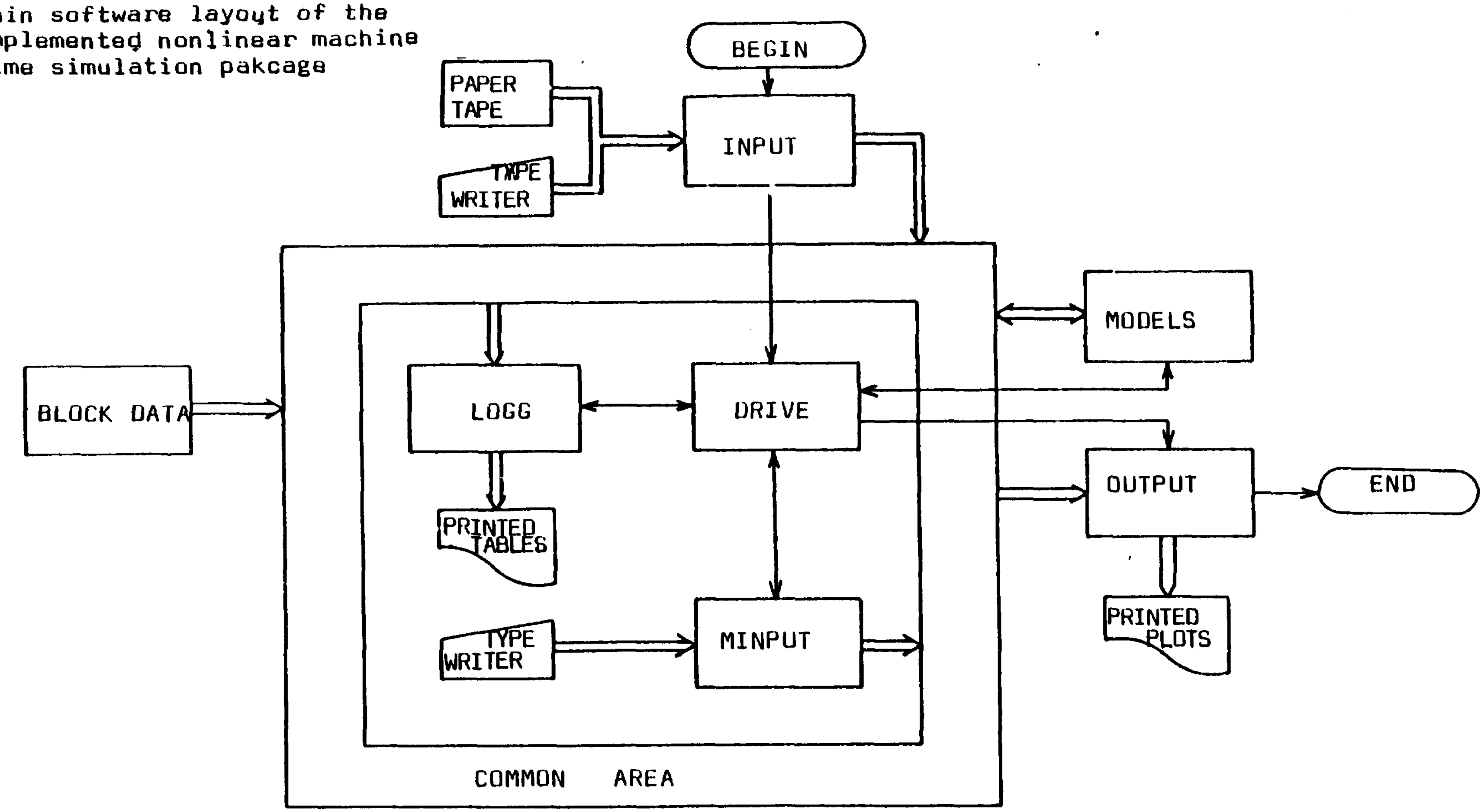


Fig. 2 Nonlinear model dynamic data flow diagram

Fig. 3

Main software layout of the implemented nonlinear machine time simulation pakcage



BLOCK DATA: Provides the IC by data statement
INPUT : Read IC optionally from paper tape and read control information for simulation run
LOGG : Prints out simulation data for a group of 7 variables. Three different groups available.
DRIVE : Driver routine calling the model programs, LOGG program and MINPUT program
MINPUT : Reads in the new values of the control variables if desired by the user
MODELS : Includes 10 model subroutines and the drum level controller program
OUTPUT : Generates a printed plot for a selected variable after the simulation run
⇒ : Data flow
→ : Control flow

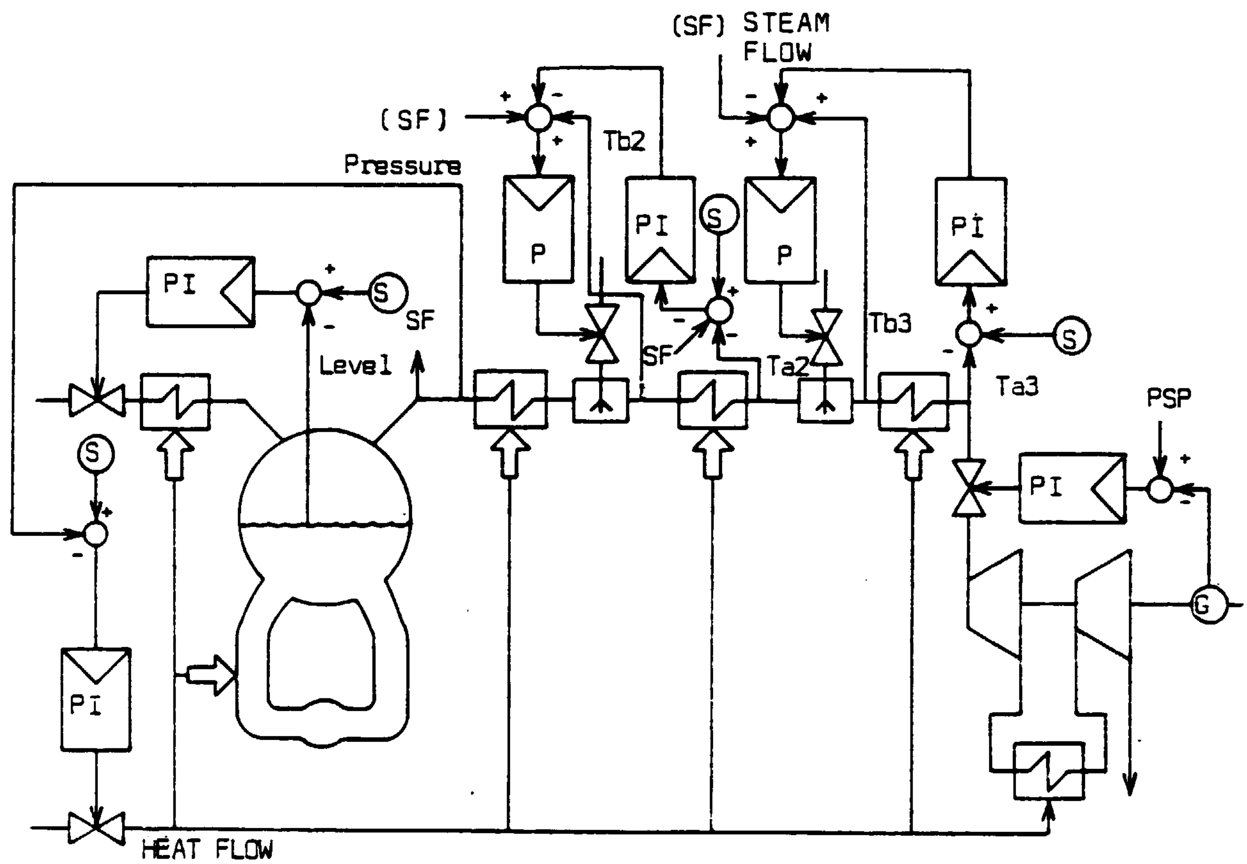


Fig. 4 _ Linear model; simulated plant process diagram

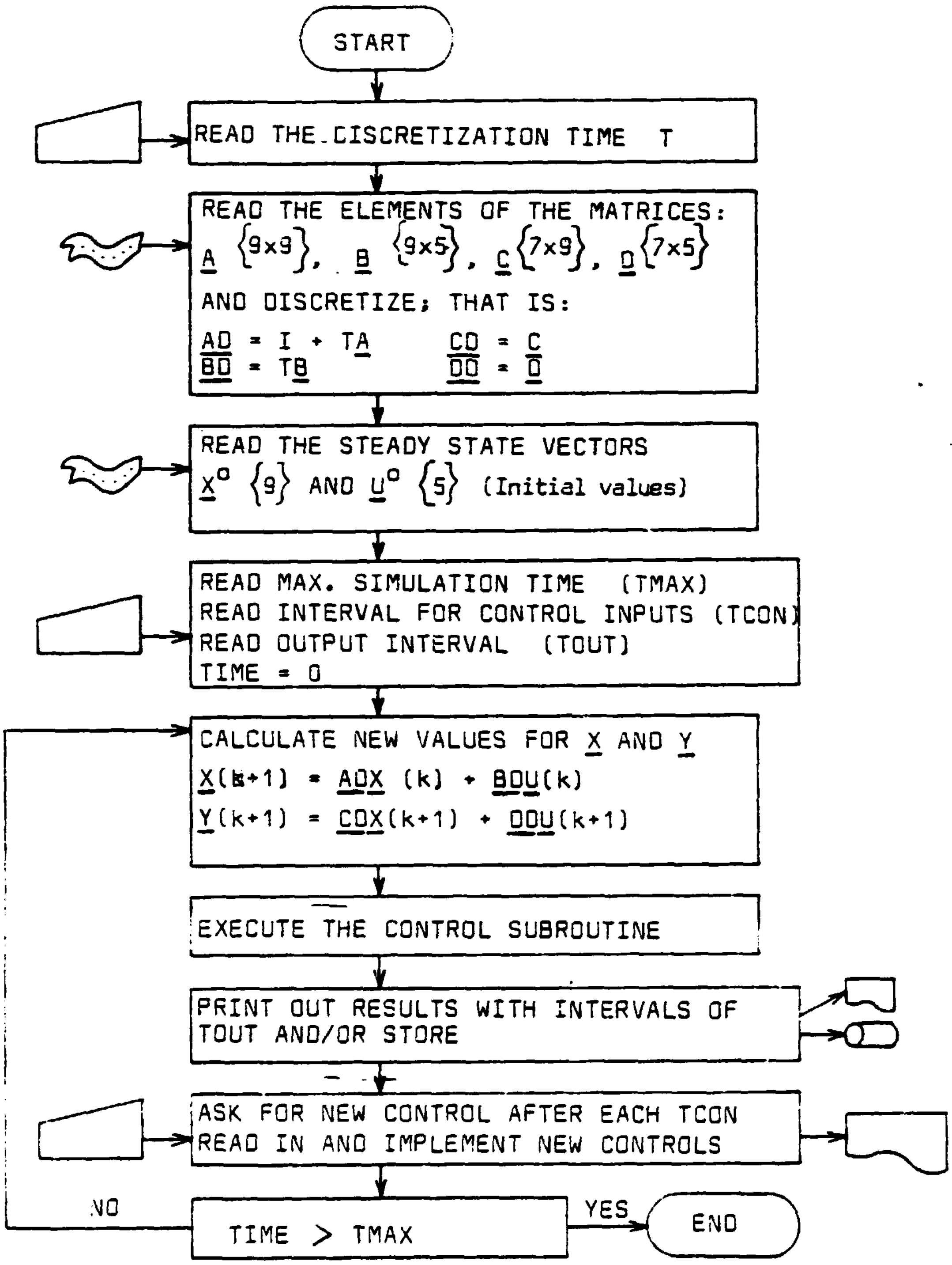


Fig. 5 Simplified flow chart of the linear simulation model

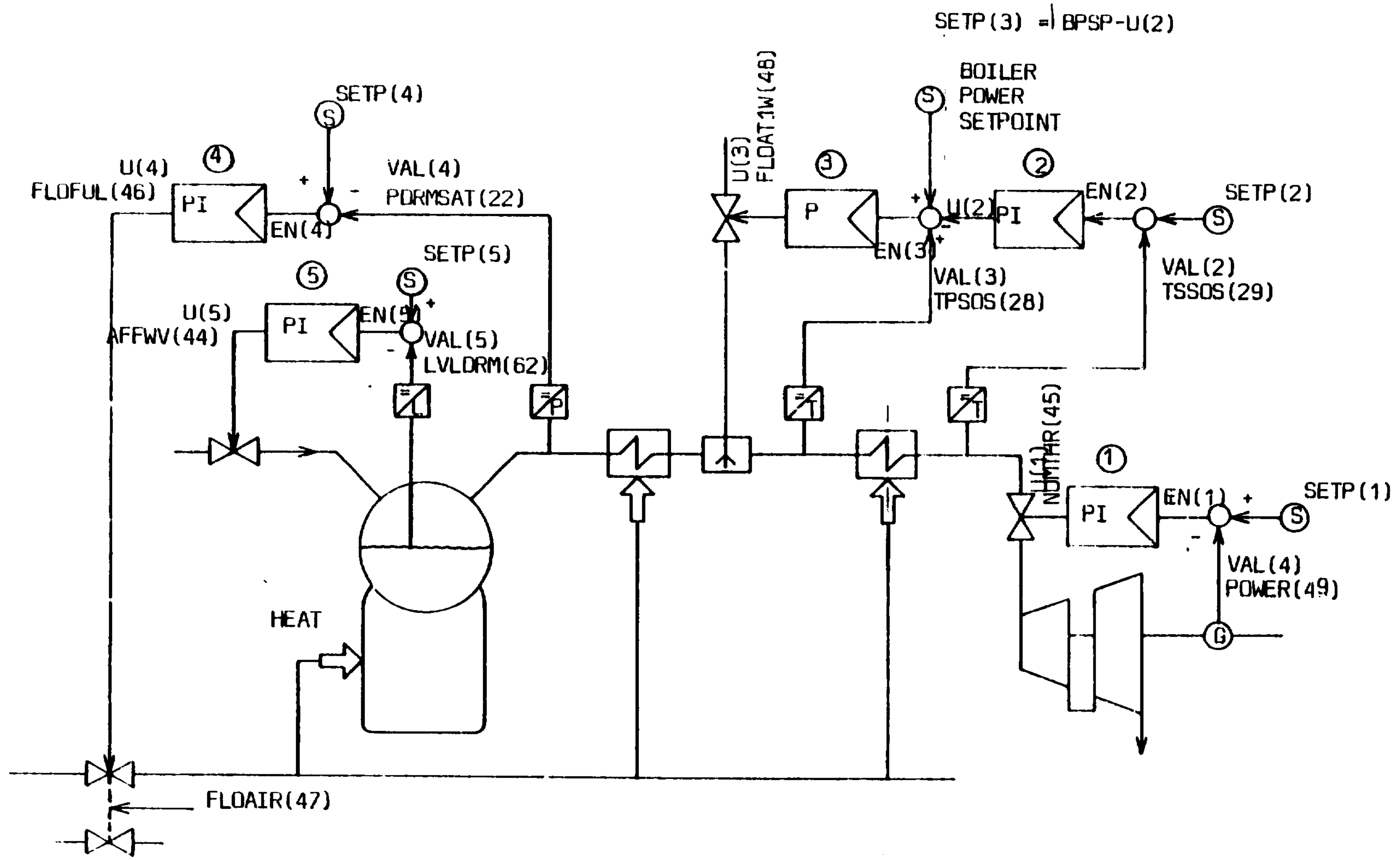


Fig. 6   A proposed system for experimenting with the nonlinear model

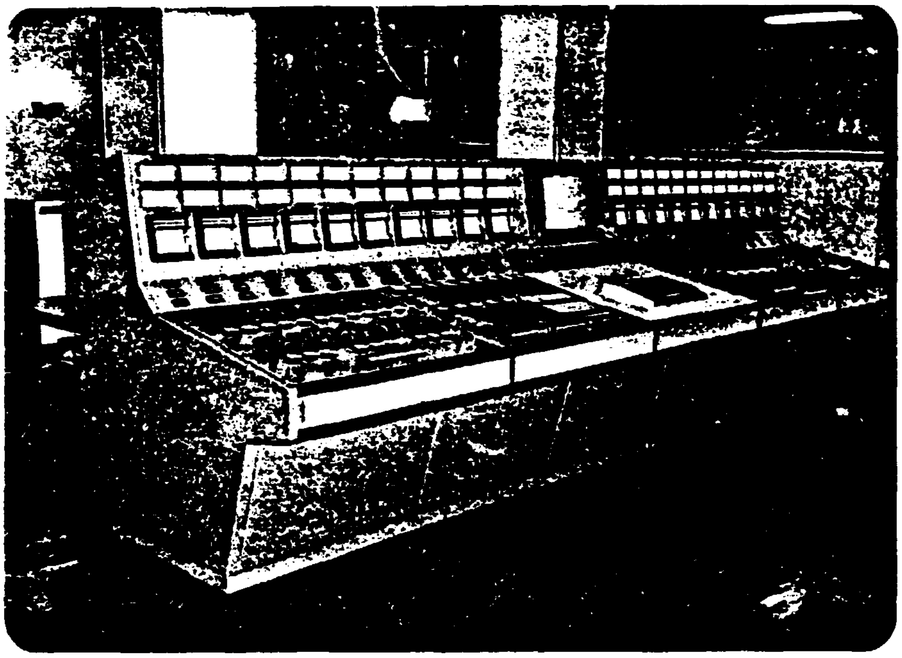


Fig. 7 The control desk and instruments at the simulation laboratory

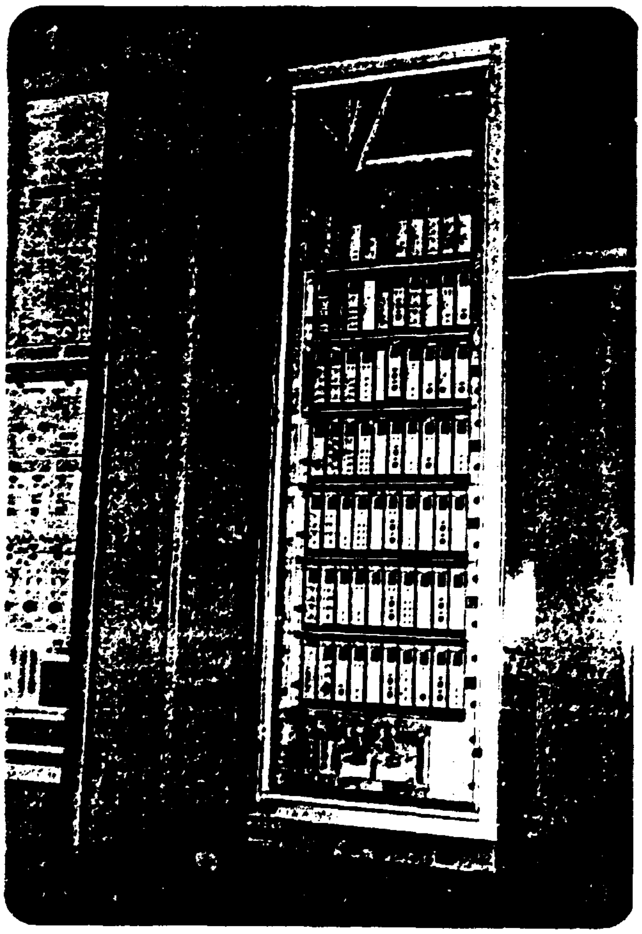


Fig. 8 Experimental rack with analog control units at the simulation laboratory

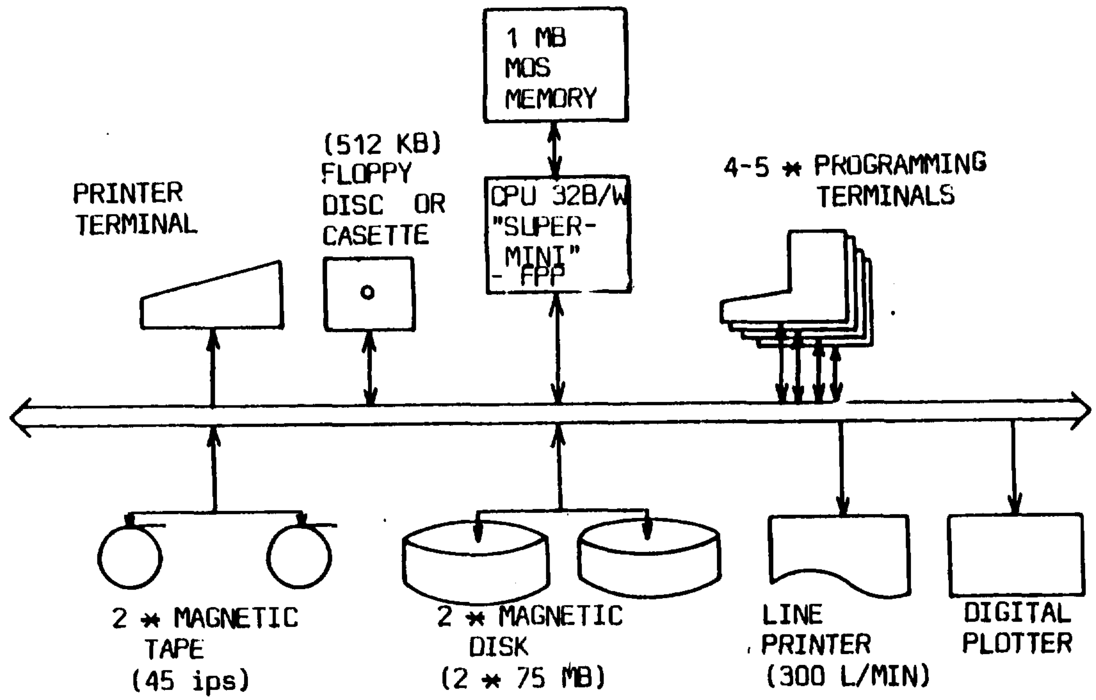


Fig. 9 Proposal for a new simulation computer facility

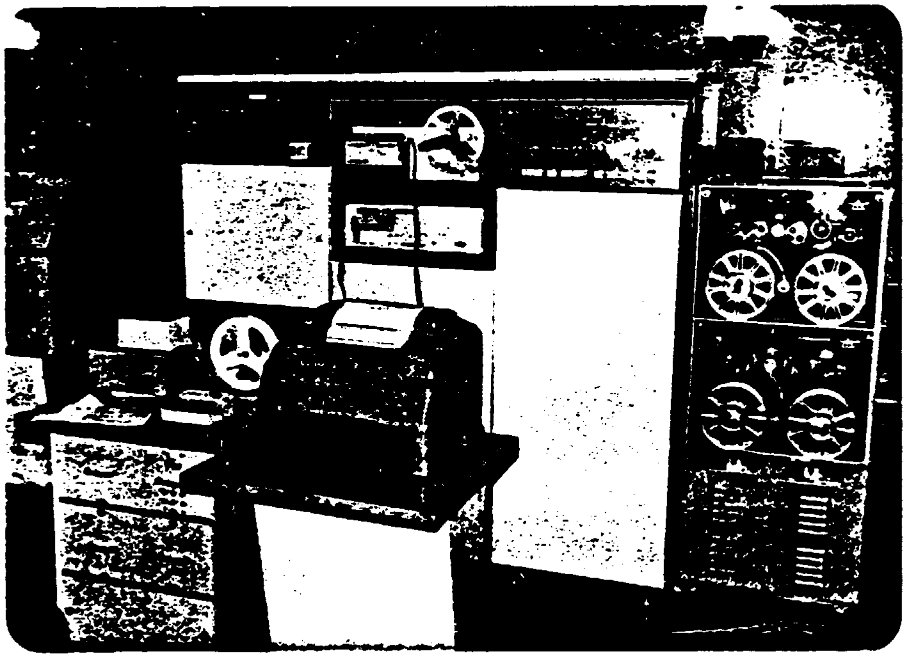


Fig. 10 The available 6 l/min console typewriter in the foreground

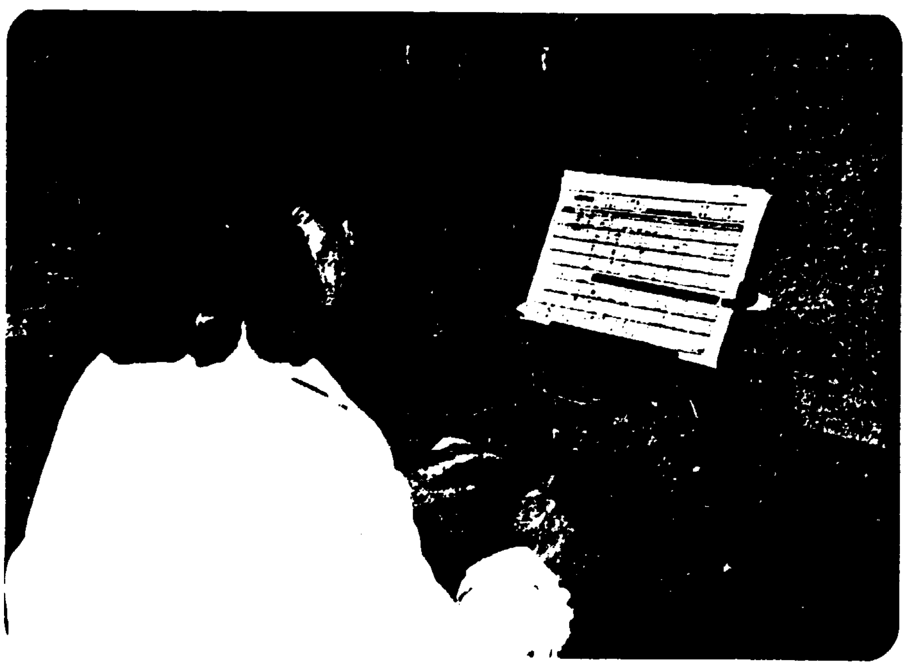


Fig. 11 The manual punch unit of the Institute

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO 6 August 1982

PROJECT IN THE PEOPLE'S REPUBLIC OF CHINA

INTERNAL

JOB DESCRIPTION
DP/CPR/79/021/11-08/31.9.B/Rev.1**

Post title	Expert in Steam Power Stations
Duration	Three months
Date required	As soon as possible
Duty station	Archeng, Heilengjiang Province
Purpose of project	To assist the country to strengthen its machinery building industry, thereby helping to increase productivity in the agricultural sector and avoid diverting resources away from the industrialisation programmes to provide emergency measures to help feed the population adequately.

Duties

The expert will work in co-operation with the First Ministry of Machine Building and will specifically be expected to:

1. Provide technical guidance and train local personnel in the following fields related to the automation of steam power stations:

   a) computer controlling technique for coal-fired units, control philosophy for a 600 Mw drum boiler and turbine plant;

   b) micro-computer applications (Zilog compatible technique);

2. Assist and give advice on simulation testing, utilisation of computers and, in particular, on the following:

   a) mathematics model and dynamic simulation of coal-fired plant processes in order to analyse transcients and to dimension power plant components;

   b) test technique of mathematics simulation, concepts on

** The revision of this Job Description is being issued due to changes in the text.

..../..

Applications and communications regarding this Job Description should be sent to:

Project Personnel Recruitment Section, Industrial Operations Division
UNIDO, VIENNA INTERNATIONAL CENTRE, P.O. Box 300, Vienna, Austria

simulation languages for a digital computer;

c) process operator simulators for thermal power plants (simulator types, standards, utilisation areas, role of simulators in the training of power plant operators, functional and technical requirements of a modern full-scope power plant training simulator);

d) detecting technique for turbine rotor thermal stress and flame in the boiler chamber.

The expert will also be expected to prepare a final report, setting out the findings of the mission and recommendations to the Government on further action which might be taken.

Qualifications — Sound educational background and wide experience in automating steam power stations.

Language — English

Background Information — The country has vast coal resources, (approximately 650,000 million tons). In electricity production, there is a general world trend to replace oil by less expensive fuels, and the country has this realistic alternative. In order to exploit these resources for electricity generation, the country is developing a 600 Mw coal fired power plant which is probably fit for a standard plant, and several similar units can be built around the country. This clearly effects benefits. In approximately five years, the first unit should be in operation. This would be an attractive alternative, even if the country should start its nuclear programme, because a variety of electricity sources ensures the safest supply. This is generally considered a basic condition for uniform industrial development in the country. So far, there is a deficit in electricity production.

The country does not have varied sources for the generation of electricity. This implies special requirements for the power plant concept e.g. the network stability and reserve power problems. A typical network contains a total power capacity of 10,000 Mw. Ten per cent is the maximum unit size allowed for stability reasons and a 600 Mw unit meets this condition.

The simulation technique and automation design will have many benefits in this connection if they are properly carried out. Since these units (600 Mw) will be base load plants, they must be designed so that high plant availability rates will be achieved. Dynamic simulation will evidently have a positive impact, for the following reasons:

a) various control alternatives can be tested in advance through simulation which is definitely less expensive than in real circumstances;

b) simulation can influence the process concepts, components and circuits in the design phase;

c) the commissioning time of the plant becomes shorter which is an obvious economic benefit;

d) the plant availability becomes higher, which has direct and indirect economic consequences;

e) the safety of the operation can be improved;

f) effects on the environment can be simulated (SO_2 and other emissions, fly-ash, thermal pollution etc.), since the plants will probably be located in densely populated areas;

g) separate processes can be dynamically simulated as part of the total power generation system;

h) dangerous situations can be analysed which is impossible in existing plants.

Simulation is an efficient tool to preanalyse the important plant properties. However, the costs are fairly reasonable compared with the plant investment costs. In Europe, e.g. a 700 - 1,000 $Kw unit cost is estimated as an average investment for a coal fired plant depending primarily on the size.

Coal has the following special features as a fuel: the handling is inconvenient; the quality varies; it erodes the boiler; it causes slagging, fly-ash, ash and various kinds of emissions; transport is a problem in the case of big units. Consequently, a careful preanalysis of the plant characteristics is justified.

1982-12-09 - 1983-02-26

W O R K   P L A N

TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M
9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

GENERAL INTRODUCTION

1

1. MATHEMATICAL NONLINEAR REAL TIME SIMULATION MODEL FOR A LARGE STEAM POWER PLANT
2. ASPECTS OF COMPUTER IMPLEMENTATION OF THE MODEL ETC.

---

1. FAMILIARI-ZATION WITH THE LITERA-TURE BROUHGT FROM FINLAND
2. PROVIDING THE FINAL WORK PLAN

CLARI-FICATI-ON OF PARA-METERS OF THE NON-LINEAR MODEL

---

2 FULL SCOPE P.P. TRAINING SIMULATORS

Introduction on nuclear and thermal power plant simulators

1. Simulator types
2. Utilization areas
3. Personnel training
4. Simulator functional specification
5. Simulator hardware
6. Simulator software
7. Simulator standards
8. Software development tools
9. Special modelling techniques
10. Outline of model programs

---

3 CONTROL SYSTEMS OF STEAM POWER PLANT AND THEIR SIMULATION

---

4 AUTOMA-TION OF S.P.P.

1. PROCESS COMPUTER
2. D.D.C.

(EXAMPLES)

---

5 IMPLEMEN-

T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S	SU	M	T	W	TH	F	S
18	19	20	21	22	23	24	25	26	27	28	29	30	31	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

TATION OF THE NONLINEAR SIMULATION MODEL:

1. Programming
2. Individual module testing
3. Model integration and testing
4. Model verification
5. Experimenting with the model
6. Implementing support routine

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6 MATHEMATICAL LINEAR REAL TIME SIMULATION MODEL FOR A LARGE STEAM POWER PLANT

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7 NUCLEAR POWER PLANT SIMULATION MODEL EXAMPLES

8

1. CONTROLLER OPTIMI-ZATION
2. SIMULATION LANGUAGES
3. DIGITAL COMPUTER IN ENTERPRISE MANAGEMENT
   - OR SOME OTHER SUB-JECTS OF INTEREST

WORKING OUT THE FINAL REPORT

SUMMARY AND CONCLUDING REMARKS

DEBRIEFING AT UNIDO (BEIJING)

DEPARTURE FOR FINLAND

NOTE. DURING AND BETWEEN LECTURES DISCUSSIONS AS REQUIRED

DECEMBER 1982

APPENDIX 2

APPENDIX 3

BENEFITS OF USING TRAINING SIMULATORS

The most important utilization area of training simulatos is the training of power plant personnel. The following advantages can be mentioned:

1. The power plant itself need not to be used in training but it can operate undisturbed.

2. Due to the special instructor's facilities the training is efficient and the training time shorter than when using other methods.

3. Training in serious malfunction and accident situations is possible. Therefore, the operators trained with the simulator are more competent than those trained without it.

4. It is possible to apply standard training situations facilitating a better trainee performance evaluation than what would be possible without the simulator.

The use of simulators in training and other areas brings about savings on the following areas:

a) The plant availability is improved because of:

- shorter commissioning period
- faster run-ups
- decreased number of unscheduled forced outages
- faster analysis of the reasons of unscheduled outages.

b) The plant operational efficiency is improved due to

- decreased number of operating errors
- better optimized operating strategies
- improved control concepts developed by using the simulator
- decreased strain and wear of plant components due to decreased number of forced outages
- improved process concepts and equipment dimensioning by using the simulator in the design phase.

APPENDIX 4

SPECIFICATION OF A SIMULATION RESEARCH COMPUTING FACILITY

General

Computer simulation is the only practical way to ensure in advance that a new plant has no major design deficiencies which are very costly if detected after the plant is already operational.

Full scope training simulators cover the entire power plant process and all operating modes including the auxiliary systems and the control room but the accuracy requirements are not very high. Main requirement is the real-time operation and that the simulator behaves realistically as seen in the control room via the instruments and displays.

Design models have to be more accurate but they do not normally have to cover the entire power plant process or the whole range of plant operations from cold shutdown to full power and back but normally one or two operating modes, frequently including abnormal and emergency situations. The control room has not to be simulated. Real-time simulation is not normally required but it would be very convenient to simulate as much faster than real-time as possible.

Ephasis is on the ease of program development, flexibility in making program modifications and setting up test runs and presenting the test results. The requirements are much the same as in the development phase of a full-scope training simulator and also the computing capacity requirements are nearly the same.

Computer hardware and software requirements for efficient research work at the Institute are outlined in the following.

Computer hardware

A representative computer hardware configuration is shown in Fig. 9. The computer should be a 32 bit/word "supermini" with virtual memory. Examples of such machines are e.g. the VAX780 and the ND500/100 system.

The memory should be of ECC-MOS type preferably ported to facilitate addition of CPU capacity if needed later. The total memory size should be 1 MB with possibility for 100 % expansion later if needed. The memory cycle time should be 200-400 ns. This can be achieved probably only by using an additicnal cache memory. The high speed and large size of the memory are required to facilitate real-time simulation of major parts of the power plant with sufficient accuracy.

Always wnen the real-time aspects are not of interest, the simulation should be performed as much faster than the real time as possible, to avoid waiting. It should be possible to do program development work (editing, compiling etc.) on another terminal while a simulation test is run on one terminal. The following computer peripherals are required:

- An efficient hardware floating point processor (FPP) is needed for the heavy floating point calculations required in simulation of plant systems.
- Real-time clock is needed e.g. for real time simulation.
- Time-of-the-year clock is needed for documenting purposes.
- A floppy disk or a casette tape unit is needed for system diagnostics.
- A console printer terminal acting as a system printer.
- An assynchronous serial line multiplexer (5-8 lines) to connect the terminals.
- 2 x 75 MB disk memory plus the controller with $\leq$30 ms average access time. Two disks are required to make disk copying possible. It is needed necessarily e.g. for back-up purposes. The disks are used e.g. to store the disk resident operating system and other system software, to keep all the user source programs (e.g. the simulation models). Editing occurs interactively from the disk by means of the editor program using programming terminals.

- 2 x 45 ips magnetic tapes are needed to store large amounts of test data for later analysis and to transfer programs and data conventiently between other organizations in China and abroad. Two tape-stations are needed for making the copying of tapes possible.

- 300 lines/minute lineprinter is needed in program development and documentation purpose and for printing out simulation results in table format.

- A digital plotter is needed to generate graphical presentations from simulation results. Such results are easier to use than numerical values in table format.

- I/O-interface should be added if any control room hardware is to be connected to the computer.

Software requirements

The computer should have an efficient standard real-time operating system with e.g. the following features:

- Full time-sharing capability and efficient interactive text editor for program development and debugging from several terminals simultaneously.

- Standard FORTRAN 77 compiler to ensure software transportability. All machine features should be fully supported by Fortran.

- Virtual memory management.

- Support of shared main memory. Two examples of suitable operating systems having the required facilities are VAX/VMS and ND Sintran III/VS operating systems.

APPENDIX 5

TRIPS

A. TRIPS TO INDUSTRY

1. ACHENG RELAY WORKS
2. HARBIN TURBINE FACTORY
3. HARBIN GENERATOR FACTORY
4. ACHENG POLYESTER FIBER FACTORY
5. ACHENG SUGAR FACTORY
6. HARBIN WATCH FACTORY
7. HARBIN ELECTRICAL INSTRUMENT FACTORY
8. YU GUAN VODKA FACTORY

B. OTHER TRIPS

1. YU GUAN DEER FARM
2. HEILONGJIANG EXHIBITION
3. HEILONGJIANG MUSEUM

APPENDIX 6

PROBLEMS CAUSING DELAY AND INCONVENCIENCE DURING THE PRACTICAL WORK

- The available Fortran IV language only accepts variable names with a maximum lenght of 6 characters. This caused renaming of a large part of the parameters employed.

- Double precision accuracy could not be used due to the small size of the core memory (32 Kw).

- Even though there is a real time clock in the computer, the real-time features are not available for Fortran programs. This caused a redesign of the software system. Instead of the original plan to build a real-time simulator a machine-time simulator (cf. Fig. 3) had to be built.

- When the first compilations were attempted, it appeared that the CPU could not have any access to the drum. The practical work had to be suspended and lectures were submitted during the 9 days which were needed for the repair work.

- The computer could only be repaired to the extent making the program compilation and execution possible but it was not possible to read from or write to the drum under programme control. This caused a redesign of the software such that variables were stored in core during simulation for later plotting. This limitation made an efficient debugging of the programme package impossible and decreased the flexibility in utilization of the package.

- The only output unit available was the 6 l/min console typewriter (c.f. Fig. 10). It was a serious bottleneck in program development. E.g. listing the entire software package took about 3 hours.

- The way to generate new initial conditions was to run the simulator in closed loop control to the desired initial condition and to dump it then on the paper tape. It, however, appeared that the punch unit could not punch so much data at any one time. Therefore, the open loop tests could not be started from the same initial conditions than in /2/.

In steady state test 21 variables has to be printed out. There is, however, space only for 7 variables at any one time in the typewriter and in core. This means, that 3 different runs have to be made to get all the 21 variable values. In order to start these three runs from the same IC the punching facility would have been required. Because it was not available we had to dump the whole Common area all the time on the slow typewriter. This took so much time taht we could not wait long enough to get a good steady state after a transient.

- When compiling the paper tape programs it appeared that the manual punch machine (Fig. 11) had made so many errors that the tapes were not useful. After repair of the puncher almost all programs had to be repunched.

- While reading the paper tape the tape reader frequently destroyed the tape which caused extra work.

- In average every third time the compiling was abborted by some internal error in the computer.

- Sometimes the program could be run through sometimes not. It was not possible to find out whether the error was in software or in hardware. Hardware diagnostics program was run once through. It found one memory location error. That was caused by bad contact and was repaired fast.

- Because of the problems with punching, inputting of the paper tape, drum storage limitation and low speed of the typewriter any ideas to generate properly commented code had to be dropped and only the necessary program statements were included. This contributes to bad programming habit and unclear coding which is difficult to understand and maintain.

APPENDIX 7

VALIDATION TEST RESULTS FOR THE NONLINEAR MODEL

A. Steady state test

The simulator was steered to a condition where the throttle pressure was 1004.1°F (±20°F) and the throttle temperature 1808.7 PSIA (±10 PSIA). After the transients had stabilized the values of the main parameters were observed and compared with the plant measurements. The results are shown in Table 7.1. The small differences between the results obtained with Acheng model and those given in /2/ are probably due to the reason that the transients were not completely stabilized when the run was stopped. The reasons for the differences between the results obtained with the model and those measured at the actual plant are thoroughly discussed in /2/.

B. Transient tests

Closed loop tests

°1 In the first test a 10 % decrease in the total throttle valve flow area (NUMTHR) should have been performed and the throttle pressure (PSSOS), throttle temperature (TSSOS) and the gross power (POWER) plotted. Accidentally an increase was performed instead of a decrease. The results are shown in Fig. 7.1. At least the correctness of the timeconstant can be verified from these results.

°2 In the second test a 6 lbs/sec increase in the spray flow was performed and the throttle temperature was plotted. Two runs were performed the results beeing shown in Fig. 7.2. In both runs the IC was somewhat different from that used in /2/. Therefore, the curves have been moved such that the starting points are at the same location. The results coinside well with those given in /2/.

Open loop tests

These tests are made to verify that the direction and trend of the parameter changes are correct. The controller program was not in operation during these tests. Because the punch unit was inoperational there was no way to generate the initial condition used in /2/. Therefore, these tests were started in a different IC which effects upon the results. However, the direction of the change should still be correct.

The total throttle flow area was increased by 10 lbs/sec. The results are shown in Fig. 7.3. The direction of the change is the same as in /2/ but the rate of change is different due to the different initial condition employed.

In the second test the spray flow was increased by 6 lbs/sec. The results are shown in Fig. 7.4.

Table 7.1 Steady state test results

VARIABLES	VARIABLE FORTRAN NAME	a ORIGINAL PACKAGE /2/	b ACHENG MODEL	c CROMBY PLANT	PERCENTAGE DIFFERENCE (b & c)
CONTROL VARIABLES					
Normalized feedwater valve area	AFFWV	0.7567	0.7563	0.6435	17.6
Number of open throttle valves	NUMTHR	6.0	6.0	6.00	0.0
Mass flow rate of fuel (lbs/sec)	FLOFUL	50.6	50.6	36.25	39.6
Mass flow rate of air (lbs/sec)	FLOAIR	485.0	485.0	471.80	2.8
Air-to-Fuel ratio		9.58	9.58	13.02	26.4
Superheater spray flow (lbs/sec)	FLAT1W	0.00	0.00	0.00	0.0
STATE VARIABLES					
Waterwall metal temperature (°F)	TWWLM	765.4	765.6	762.6	0.39
Drum water volume (cu. ft)	VLDRMW	535.0	535.0	535.0	0.0
Steam density in drum (lb/cu.ft)	RODRM	5.148	5.162	5.132	0.58
Steam density in PSO (lb/cu.ft)	ROPSOS	3.282	3.23	3.177	1.7
Steam density in SSO (lb/cu.ft)	ROSSOS	2.220	2.20	2.263	2.78
Steam enth. in PSO (Btu/lb)	HPSOS	1303.8	1311.4	1318.9	0.57
Steam enth. in SSO (Btu/lb)	HSSOS	1490.6	1497.6	1483.9	0.92
SELECTED OUTPUT VARIABLES					
Gross power output (MWe)	POWER	146.51	148.9	198.80	25.1
Steam mass flow rate (lbs/sec)	FLSSOS	397.63	397.0	385.84	2.9
Steam temp. in Drum (°F)	TDMSAT	632.84	633.1	632.70	0.06
Steam temp. at PSO (°F)	TPSOS	753.08	762.2	770.90	1.13
Steam temp. at SSO (°F)	TSSOS	1015.83	1027.4	1004.10	2.32
Steam press. in Drum (PSIA)	PDMSAT	1957.7	1961.3	1963.7	0.12
Steam press. at PSO (PSIA)	PPSOS	1887.8	1891.5	1887.9	0.20
Steam press. at SSO (PSIA)	PSSOS	1796.5	1799.1	1808.7	0.53
Heat transfer rates (Btu/sec)					
- in waterwalls	QWWL	236500.	236171.	230730.	2.36
- primary superheater	QPSO	64520.	66949.6	68320.	2.0
- secondary superheater	QSSO	74270.	73450.3	63200.	16.2

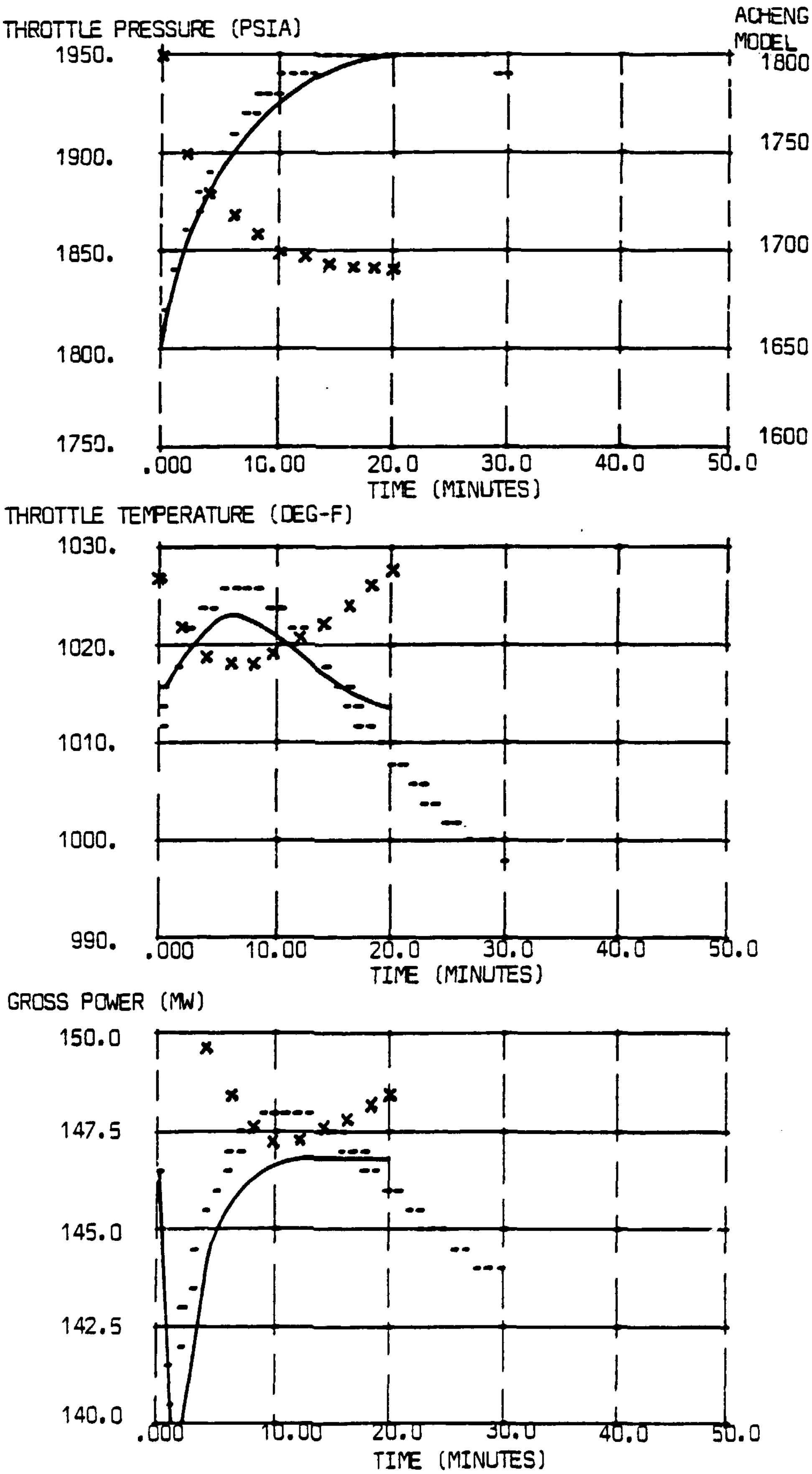
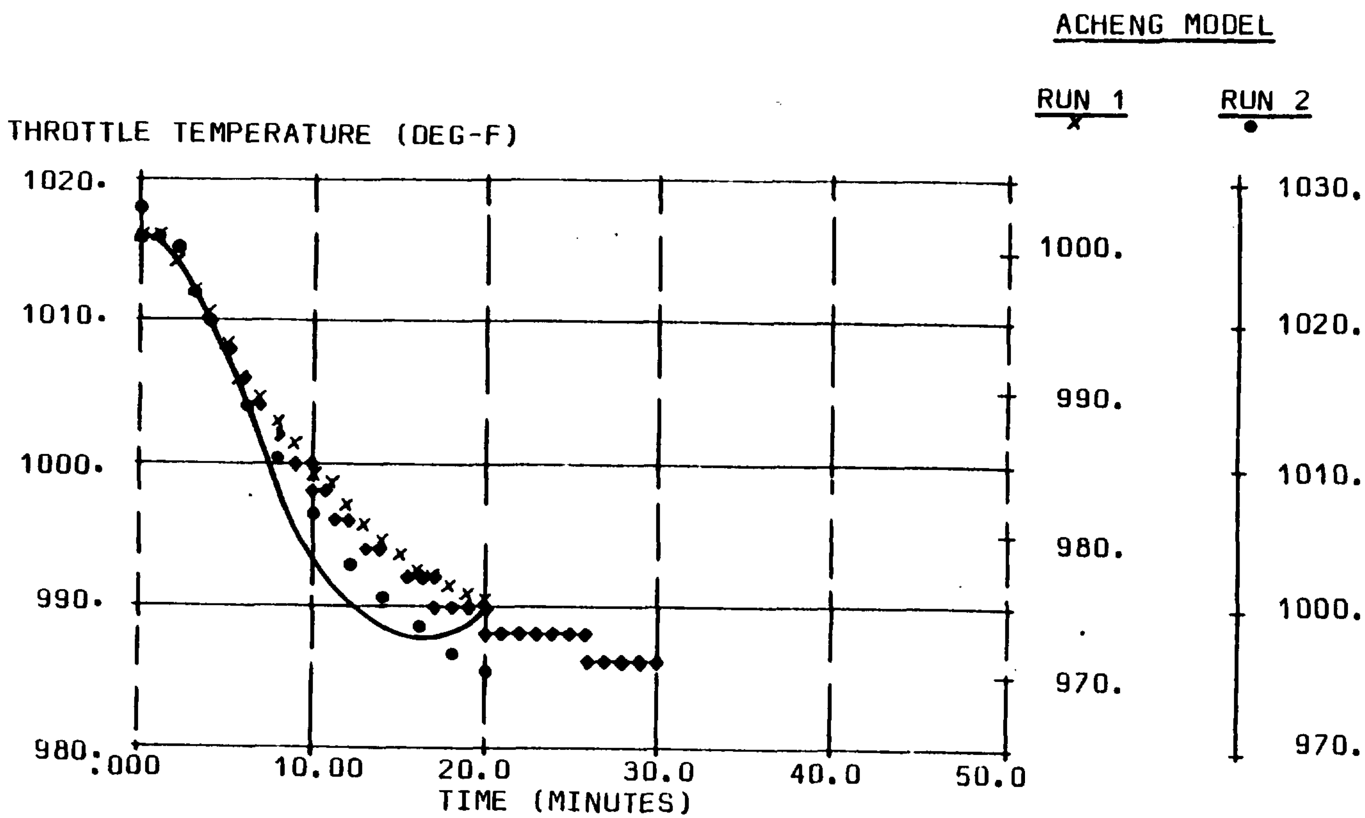


Fig. 7.1 Closed Loop Response to a Step Decrease (increase in case of the Acheng model x) in Throttle Flow Area

Fig. 7.2 Closed Loop Response to a Step Increase in Spray Flow



◆ = Simulation (/2/)

Full line = Plant Measurement

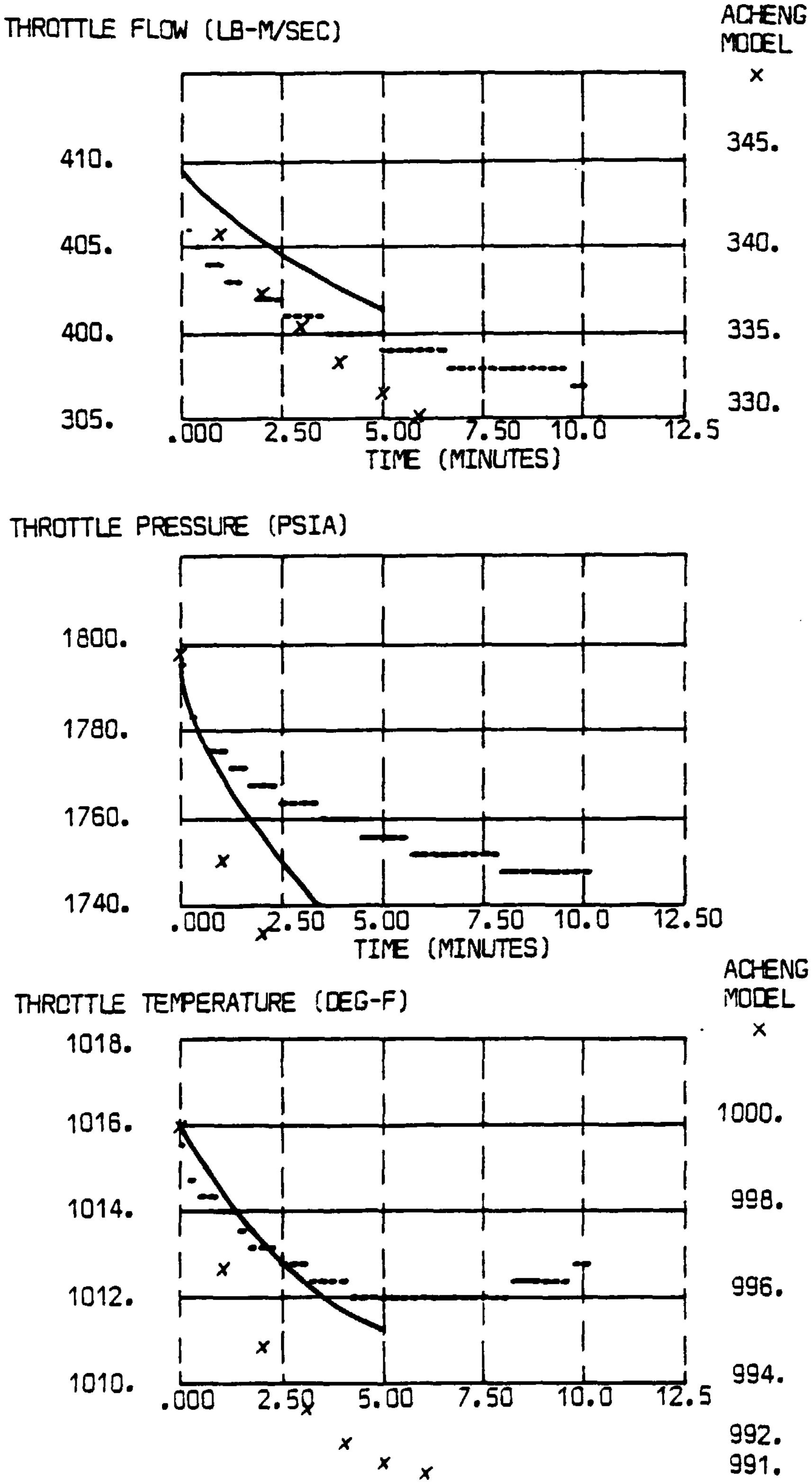


Fig. 7.3 Open Loop Response to a Step Increase in Throttle Flow Area

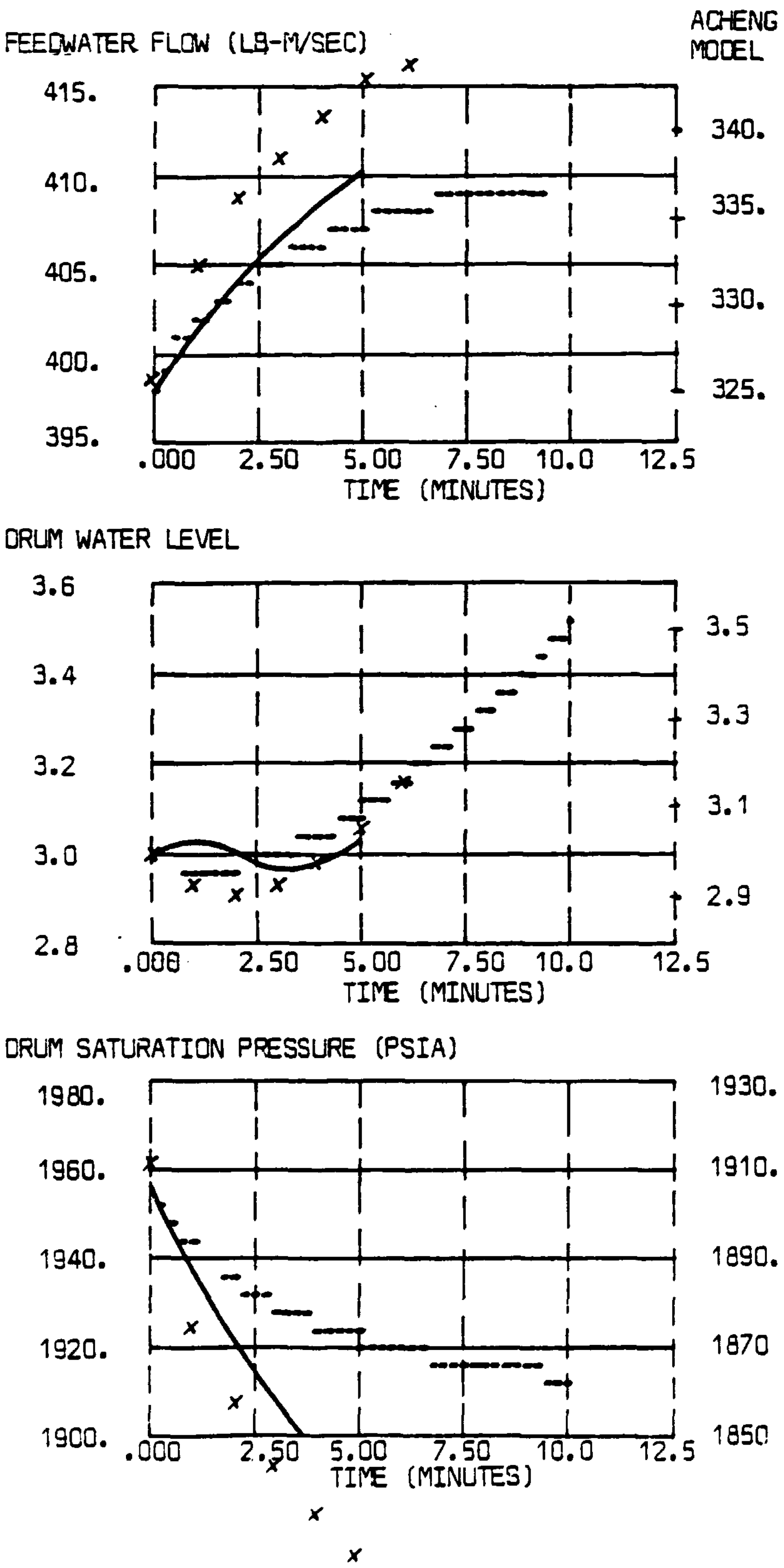


Fig. 7.3 continued

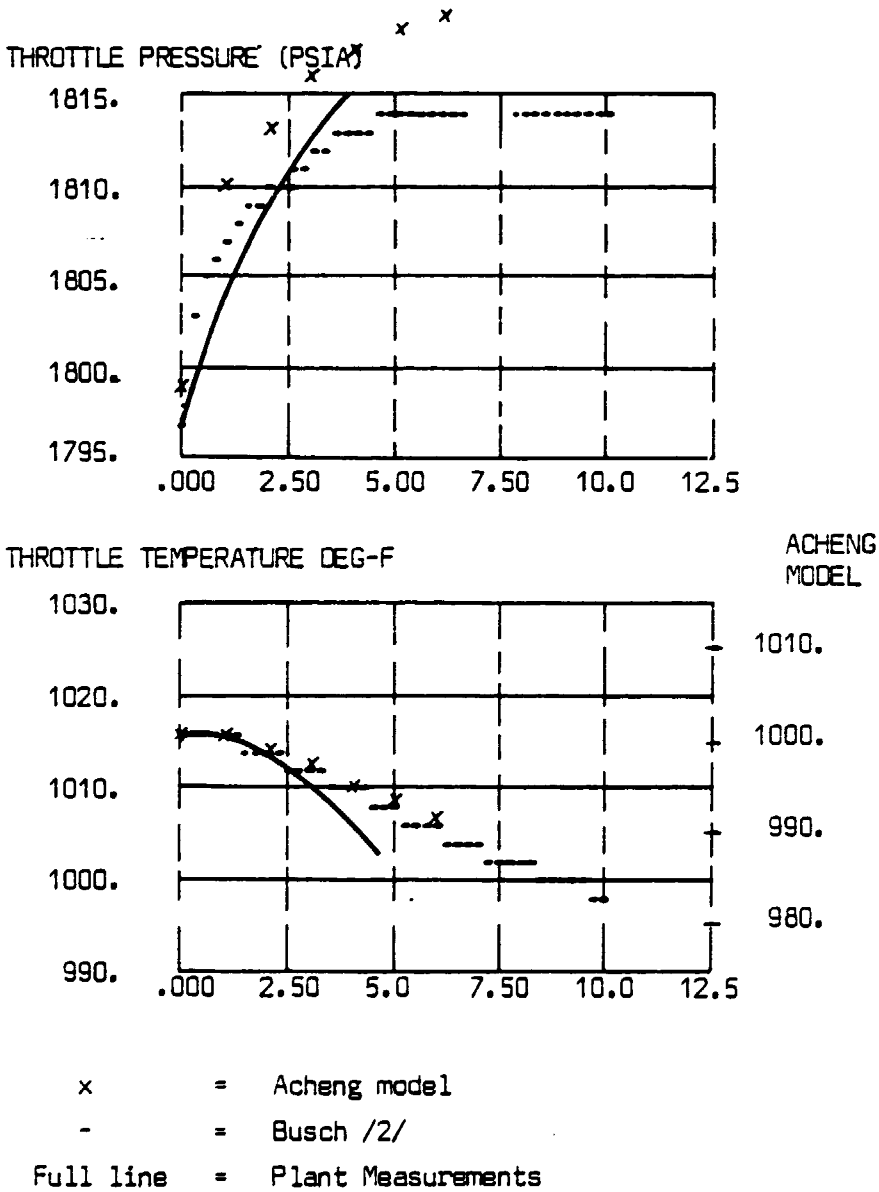


Fig. 7.4 Open Loop Response to a Step Increase in Spray Flow

APPENDIX 8

LIST OF LITERATURE LEFT IN THE INSTITUTE

The literature left in the Insitute includes all publications /1/ - /14/ listed under "Literature references" on p. 32. In additon, about 70 kg of other literature was provided. The books and some important standards are only listed below:

BOOKS:

1. John W Brewer
Control systems analysis, design and simulation"
1974 (548 p).

2. A.L. Freedman and R.A. Leeds
"Real time computer systems" 1977, (277 p).

3. A.M. Lister
"Fundamentals of operating systems", (144 p).

4. P.H. Enslow Jr. (Editor)
"Multiprocessors and parallel processing" (209 p).

5. E. Yourdon
"Techniques of program structure and design"
(364 p).

6. C.J. Date
"An introduction to data base systems", (366 p).

7. Stewart and Atkinson
"Basic analogue computer techniques", 1967.

8. B.L. Amstadter
"Realiability Mathematics-fundamentals, practices, procedures", (307 p).

9. N.A.J. Hastings
"Dynamic Programming with management applications"
(173 p).

10. Hadley
"Linear algebra"

11. INTEL
MCS-85 TM User's Manual, Sept. 1978

12. VAX Technical Summary
Digital Equipment Corporation (DEC).

OTHERS:

1. "Guide to the application of digital computers to nuclear reactor instrumentation and control" BS 6078: 1981 (IEC 643-1979), BSI

2. "Trial use standard criteria for the design of the control room complex for a nuclear power generating station". ANSI/IEEE Std 567, Oct. 1980, ANS.

3. "Nuclear power plant simulators for use in operator training" ANSI/ANS - 3.5 - 1981, ANS,

4. "Selection, qualification and training of personnel for nuclear power plants" ANSI/ANS - 3.1 - 1981, ANS.

APPENDIX 9

LOCAL REPRESENTATIVES MET DURING THE MISSION

A. ACHENG RELAY WORKS

1.	Pei Zhepeng,	Head of Acheng Realy Works
2.	Long Han-he,	Chief Engineer
3.	Liu Yi-zheng,	Assistant Chief Engineer
4.	Yan Guo-hua,	Chief Engineer of Insitute
5.	Han Jing-yong,	Assistant Director of Institute
6.	Jiang Long-cheng	Assistant Director of Institute
7.	An Ya-ming,	Dean of office of the Works
8.	Lei Yun-shan,	Section chief of Institute
9.	Gao Shi-qian,	Section chief of the Reception
10.	Che Xian-Yun,	Division Dean of the Institue (engineer)
11.	Chan Kuang-lien,	Engineer, interpreter

B. THE MINISTERY OF MACHINE BUILDING INDUSTRY

1.	Li Pei-Zhang,	Vice Chief Engineer, Director of Import and Export Department
2.	Jiang Ya-zu,	Import and Export Department
3.	Jao Zhen,	Foreign Affairs Bureau

C. HEILONGJIANG FOREIGN AFFAIRS OFFICE

1.	Liu Wei,	Deputy Director
2.	Li Chung-qing,	Assistant Director
3.	Mr Han,	Section Chief
4.	Zhou Zin,	Manager, China National Machinery and Equipment Import & Export Co.
5.	Wen Yu Pei,	Section Chief, as above

D. THE COLLAEGUES IN ACHENG

1.	Fu Yu-bin,	Software specialist
2.	Shu Ming-hei,	Hardware specialist
3.	Du Hao-chun,	Modeling specialist
4.	Wang Be,	Software specialist
5.	Ma Yan-hua,	Programming specialist
6.	Wan Hen-ping,	Programming specialist.