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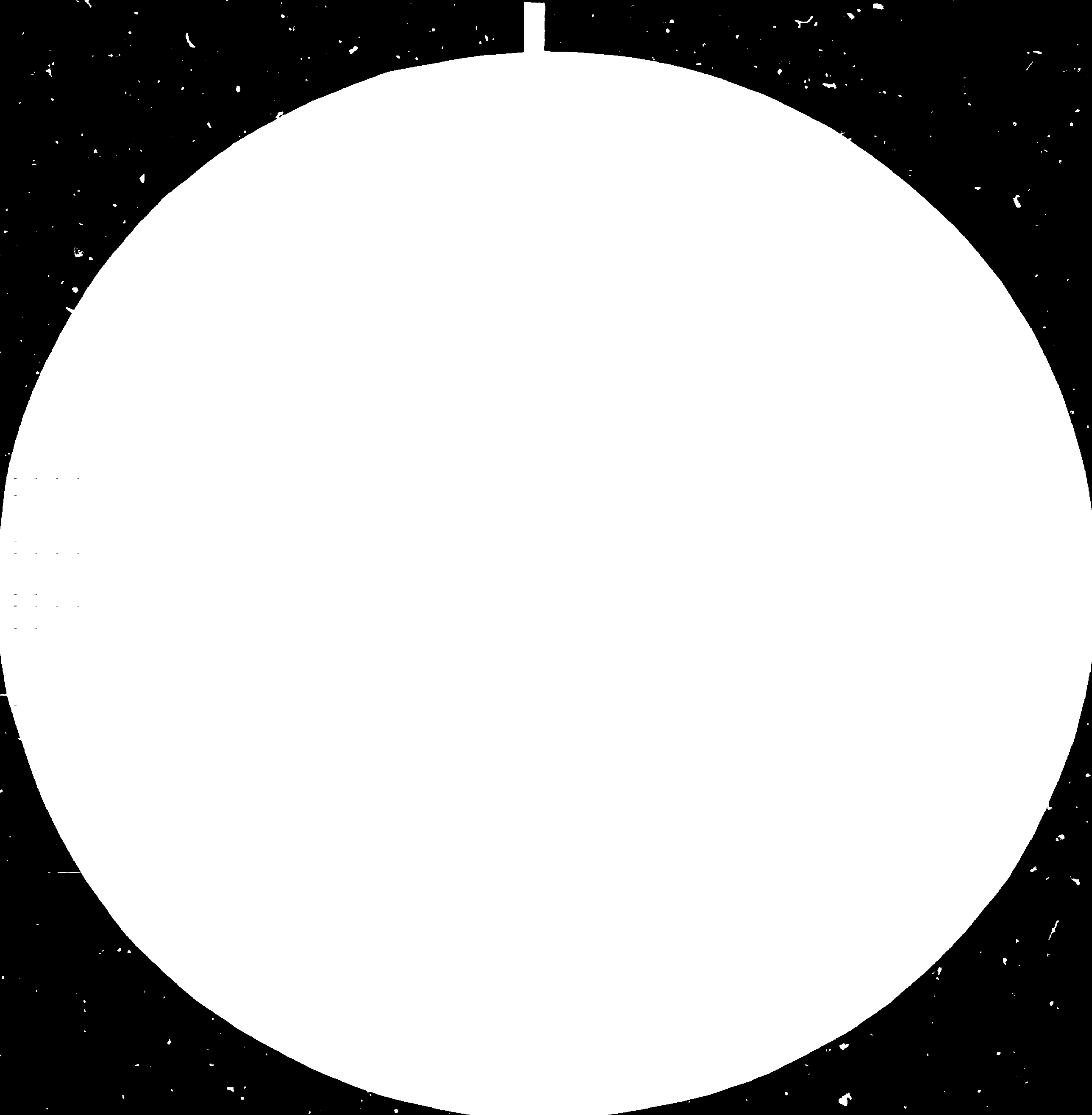

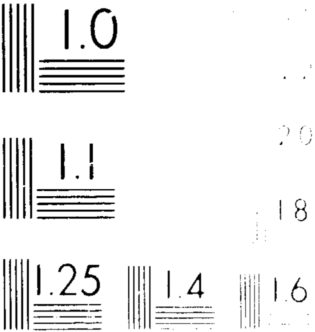
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DP/ID/SER.A/350
19 March 1982
English

MATERIALS TESTING

DP/CPR/79/021

CHINA .

Technical Report: Design of a materials fatigue testing laboratory *

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 Antony J. Morrison,
materials testing expert

United Nations Industrial Development Organization

Vienna

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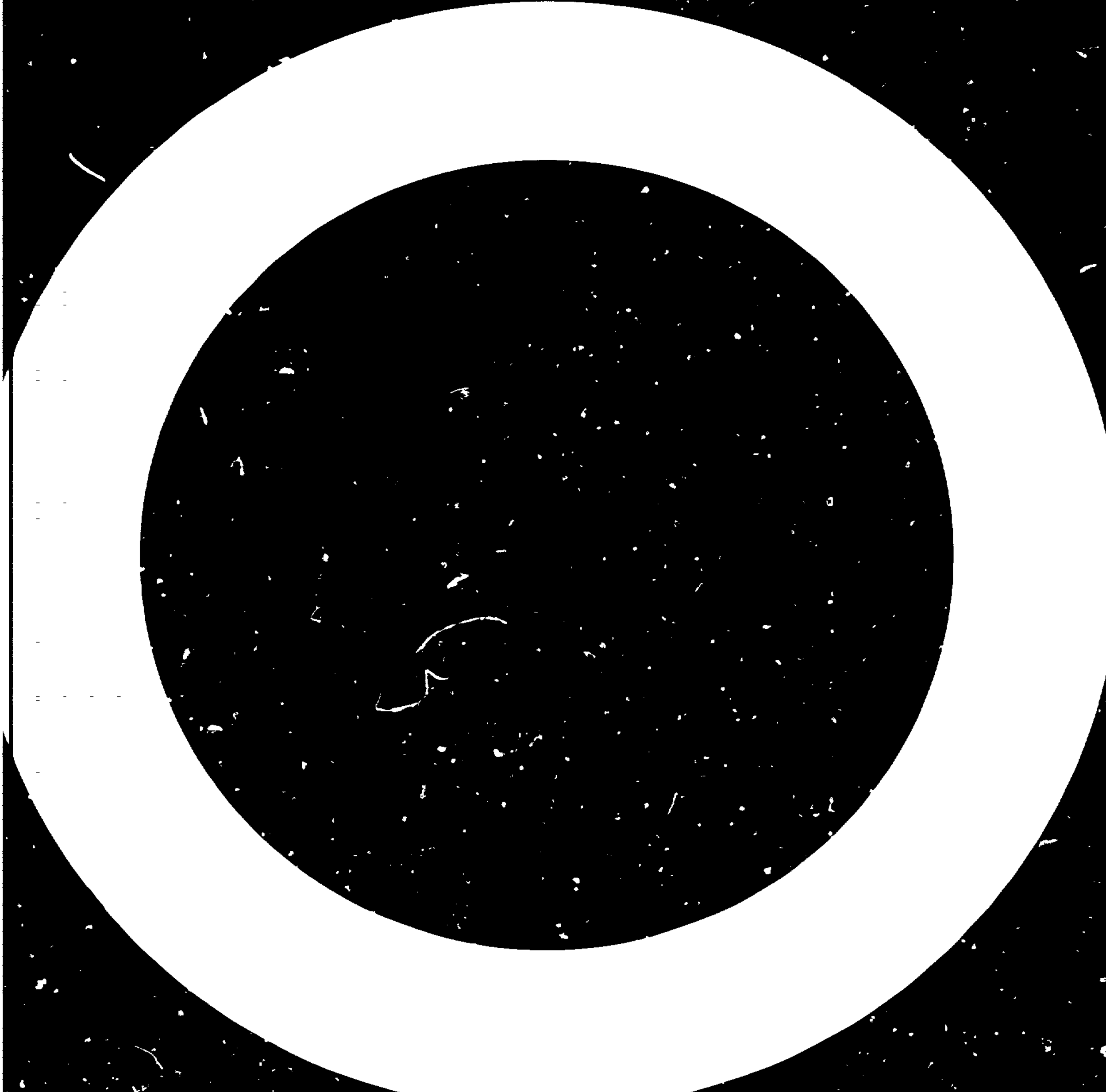

C O N T E N T S

ABSTRACT

The work described in this report is a contribution to the Development Programme DP/CPR/79/021. The purpose of the project is to assist the country to strengthen its machinery building industry.

This work on materials testing was carried out mainly at the Shanghai Materials Research Institute within a three month period beginning 1st March 1981. Main objectives were to ascertain the existing level of fatigue testing technology and provide technical guidance in the design and specification of a new centralized materials fatigue testing laboratory. Main conclusions are that the present level of materials testing technology has serious limitations in the three areas of servohydraulic test machines, instrumentation and digital computing facilities.

It is recommended to the First Ministry of Machine Building that top priority be given to the capital investment required and the training of engineers in these critical areas. It is also recommended that further UNIDO technical assistance be directed towards the specialized training requirements and to a consideration of financial assistance in the establishment of the new materials testing laboratory.

1. INTRODUCTION

The request for UNIDO technical assistance was received from the *First Ministry of Machine Building Industry.* The duties defined in the job description for the materials testing mission are given in appendix 1.

Further discussions were held in Beijing on the 6th and 7th March 1981 with officials from the Institute of Machinery Science and Technology, FMMBI to determine a suitable programme of work to achieve the mission objectives. It was agreed to visit a number of the research institutes that are directly controlled by the above institute to obtain a comprehensive understanding of the existing level of materials testing technology and to discuss with the engineers at the various institutes state-of-the--art materials and components fatigue testing techniques. Visits of a similar nature to a number of factories and manufacturers of engineering plant would also be undertaken.

For reference purposes a list of the various research institutes and an indication of their area of work is provided in appendix 2.

At a further meeting in Shanghai on 9th March 1981 with officials from the Shanghai Materials Research Institute a more detailed working programme, as shown in appendix 3, was accepted as a basis of implementing the materials testing mission.

The working programme contained two main items:

(i) Lectures, visits and technical discussions;

(ii) Design of a Materials Testing Laboratory.

2. LECTURES, VISITS AND TECHNICAL DISCUSSIONS

Two lectures were presented at the Shanghai Science Hall before an invited audience of engineers on Friday 20th and Monday 23rd March. The lectures were arranged to encompass as many of the topics listed in the Working Programme, appendix 3, as possible within the limitations of the time available for their preparation and availability of data in a format suitable for lecture presentation. A limited number of slides were shown to illustrate the lectures and use was made of an epidiascope to display diagrams and graphical data. A synopsis of the lectures is given below.

A. Lecture No. 1: Application of Fatigue to the Design of Mechanical Engineering Products

In the design of engineering components and structures there are a number of factors that must be taken into consideration if premature failure due to fatigue is to be avoided. These factors may be conveniently classified under three main headings:

(i) Material fatigue strength data

The basic fatigue strength of materials is dependent on such factors as surface finish and condition, temperature, environment, stress conditions and thefrequency and sequence of the application of stress cycles. In the next lecture an outline of current methods in use by many laboratories for the determination of basic material fatigue strength data will be given.

(ii) Service loading data

This is particularly important requirement as the data is required to allow analytical fatigue life assessments to be carried out and also the laboratory testing of materials and components under simulated service loading conditions.

(iii) Stress analysis

Although there has been significant advances in computer based stress analysis methods, this is a difficult problem faced by the engineering designer as fatigue occurs at very localized region, often an insignificant detail, in the component or structure. The stress analysis is further complicated by dynamic effects such as resonances and much work is now being carried out to determine the dynamic response of components and structures using analytical and experimental methods of model analysis.

Even when all of the above factors have been taken into consideration during the design process there remains considerable uncertainty as to the ultimate service performance of many new designs of engineering components and structures. In recent years advances in fatigue testing technology has permitted the testing of fullscale prototype engineering components and structures in the laboratory.

The lecture concludes by showing examples of the use of servo-hydraulic test machines for the fatigue testing of materials and simple components and of large-scale structural test facilities in use at the author's laboratory.

B. Lecture No. 2: Materials Testing and Fatigue Life Estimation Methods

In recent years with the introduction of servohydraulic test machines and the development of minicomputers there has been a very significant advance in materials testing technology. Considerable effort has been directed towards studying the cyclic stress-strain behaviour of materials and determining basic parameters that best describe the fatigue resistance of materials. Central to such work is the study of plastic strain as fatigue is dependent on some plastic strain occurring at localized regions. Thus current work in materials testing involves such concepts as the monotonic stress-strain curve, cyclic stress-strain curve and elastic/plastic strain life curves. The lecture will describe these topics and also introduce the use of a computerized materials testing system for Neuber control testing i.e. the simulation of the local stress-strain behaviour at a notch using a smooth materials test specimen. The lecture concludes by describing current computerized fatigue life estimation methods based on the use of stress and strain life data, Rainflow cycle counting method and Miner's linear cumulative damage rule.

C. Technical Discussion Sessions

On conclusion of the lectures technical discussion sessions were conducted at the Shanghai Science Hall. Four sessions were held each of approximately two hours duration. To illustrate the wide ranging nature of these discussions and also the specialized nature of fatigue problems of interest to local manufacturers of engineering plant and machinery products, typical questions raised at the discussion sessions are listed in appendix 4.

Technical discussions and forums were also held during the visit to the Zhengzhou Research Institute of Mechanical Engineering and at a number of factories. The questions and topics discussed are also listed in appendix 4.

During the various visits particular attention was paid to the nature of the materials test work that was being carried out and the present level of material and component fatigue testing technology.

3. OBJECTIVES OF THE NEW MATERIALS TESTING LABORATORY

It is intended that the proposed centralised materials testing laboratory be established at the Shanghai Materials Research Institute. The basic purpose of the new laboratory will be to carry out fatigue testing of a range of engineering materials under a variety of stress and environmental conditions to obtain strength data that will allow the optimum selection of materials for specific engineering applications. It is also intended that the new laboratory will have test facilities suitable for the fatigue testing of simple components.

Testing will be carried out mainly on materials and components used in the construction of gas and steam turbines, pressure vessels, automobiles and offshore oil drilling equipment. Studies will be carried out on the effects of random loading, temperature, environment and also low cycle fatigue and fatigue creep interaction.

4. MAIN TEST EQUIPMENT REQUIREMENTS

In order to carry out the intended function of the new laboratory it will be necessary to provide capital investment in the following three main equipment areas:

(i) Servohydraulic test machines;

(ii) Instrumentation equipment;

(iii) Computer systems.

Before specifying and advising on the purchase of new test machines consideration was given to the possibility of improving the performance of the existing servohydraulic test machine manufactured by Hongshan Testing Machines in China. Examination of the machine, at present in use at the Shanghai Materials Research Institute, indicated that the obtainable dynamic performance was severely limited by the quality and reliability of the high pressure hydraulic system components, servovalve and the stability of the electronic control system. At present therefore, it is considered that it would not be economically advantageous to replace all these parts of the existing servohydraulic machine with foreign manufactured items as considerable time and expertise would be required and there would be no guarantee that integration of the necessary components would result in a reliable and useful test machine.

A. Specification of New Servohydraulic Test Machines

To carry out the programme of materials testing work envisaged the machines specified in Appendix 5 are considered to be necessary. It should be noted however, that the number and selection of the new test machines will be dependent on the capital expenditure funds available at each stage in the establishment of the new materials and components test laboratory. It may be important therefore, to consider the optimum distribution of capital expenditure between the test machines, instrumentation, computing and the component test requirements. In the absence of financial planning and budgeting information it has not been possible to comment on this aspect. However, if it is necessary to phase the establishment of the new laboratory it is recommended that maximum priority be given to obtaining a computerized materials test system, comprising Test Machines Nos. 1 and 2 complete with the appropriate computer equipment, as the first stage in the construction of the new laboratory. This would form an ideal basis in the training of engineers in the use and application of servohydraulic and computer systems. Extension of the hydraulic power supply system and the addition of larger scale test machines can proceed as capital funds become available.

B. Component Testing Requirements

(i) Servohydraulic Loading Actuators

To carryout the fatigue testing of the anticipated range of engineering components the following sizes of loading actuators would be desirable:

Number Required	Static Load Capacity kn (Tonf)	Total Stroke mm (Ins)	Servovalve Size l/min (GPM)	
2	± 25 (± 2.5)	100	68	(15)
2	± 50 (± 5.0)	100	137	(30)
1	± 100 (± 10.0)	100	137	(30)
1	± 150 (± 15.0)	100	137	(30)

The loading actuators are to be supplied complete with internally mounted displacement transducers and appropriate load cells. Swivel mountings to suit both ends of the actuators will be required.

(ii) Control Equipment

It would be preferable if the servocontrol equipment for use with the loading actuators was of a similar type to that fitted to the servohydraulic test machines in the interests of standardisation and to minimise the number of spares.

Six control channels will be required complete with conditioning modules to suit the load cells and displacement transducers fitted to the loading actuators supplied. Overload cut-out modules should also be obtained.

Hydraulic start up panels, one for each control channel, to operate the solenoid valves fitted between each loading actuator and the hydraulic ring main will also be required.

(iii) Component Test Rigs

To carry out the testing of components a test rig to suit the particular component to be tested will require construction. To facilitate this a T slotted base plate is normally used upon which modular test stands can be mounted.

In the design of test stands and test fixtures attention should be given to obtaining an adequate stiffness and to ensure, as far as possible, that natural resonances of the mechanical fixtures are above the highest input test frequency to be used.

(iv) Hydraulic Power Supply

To supply the necessary hydraulic power to the servohydraulic test machines and the component testing actuators a centralised hydraulic pump room with a hydraulic ring main distribution system is advisable. This will facilitate the installation of electrical power wiring and cooling water requirements. Also, if a number of identical hydraulic pumping units are installed maintenance, servicing and the keeping of spare parts will be simplified. This arrangement will help to minimise any interruption to the test work as repairs and servicing can be undertaken on anyone of the pumps while the remainder maintain hydraulic power.

If all the test machines as specified and say two of the component test actuators were simultaneously in operation under full drive constant amplitude conditions the maximum hydraulic flow requirement would be approximately 1,200 1/min (264 GPM). This is a most unlikely situation and a more realistic estimate of the maximum simultaneous flow would be around 600 1/min (132 GPM).

It is suggested that four hydraulic pumping units each of approximately 182 1/min (40 GPM) arranged in parallel to give a total hydraulic flow capability of 728 1/min (160 GPM) would be a reasonable compromise as to the number and size of hydraulic pumping units to be installed in the hydraulic pump room. It would be advisable to leave space for an additional pump in case of any future extension of the servohydraulic test facilities.

Each pump should be a constant pressure variable flow type to minimise electrical power consumption.

The maximum electrical power required will be approximately 360 KW (483 H.P.). Cooling water requirements, at approximately 24°C (75°F), will be around 228 1/min (60 GPM) and a closed circuit cooling system, complete with a water cooling tower, may be necessary.

The hydraulic ring main should be fitted with electrically operated solenoid hydraulic pressure on/off valves. One for each test machine and six or more in the component testing area.

C. Instrumentation Requirements

The instrumentation requirements of the new laboratory may best be considered under the following headings.

(i) Test Machines

The servohydraulic test machines will normally be supplied complete with its own control system to allow the testing of material test specimens under load or displacement control. A load cell to suit the load capacity of the test machine will therefore be supplied. To allow the testing of specimens under strain control an extra D.C. conditioning module would be required.

Additional instrumentation recommended for each test machine: Oscilloscope, simple low cost instrument for monitoring demand and feedback signals.

Function generator, with sine, triangular and square wave functions.

Cycle counter, for recording the total number of loading cycles when carrying out constant amplitude testing.

Amplitude measurement unit, for use in constant amplitude testing. Either a plug in module supplied by the test machine manufacturer or a max-min digital voltmeter made by various instrumentation manufactures.

(ii) Random and Service Load Simulation Testing

In carrying out this form of testing on both materials and engineering components signal generation and signal analysis and measurement equipment will be required. It should be noted that a mini-computer system can carry out these duties and has the added advantage of being much more flexible. This will be further discussed in the section dealing with computer systems. However, some separate instruments such as a random noise generator, variable bandpass filter and RMS measuring equipment will be extremely useful to have. In particular, in order to monitor the level of a random signal applied to the test specimen or component a digital type true RMS instrument and peak measuring instrument is required.

(iii) Strain Measurement and Service Data Recording Equipment

In order to carry out the testing of materials and components under simulated service loading conditions it will be necessary to obtain service strain data. Although it is possible that the manufacturers of the actual engineering components to be tested may be able to supply this data it is desirable that the new materials and components testing laboratory has a certain amount of the equipment necessary to carry out this work.

For dynamic strain measurements, a seven channel strain gauge conditioning and amplifier unit and a seven channel F.M. tape recorder would be suitable. A battery operated portable system for use in the field and the laboratory would be preferable.

(iv) Instrumentation Laboratory Equipment

As the new testing laboratory will have a considerable amount of servo-control equipment, signal generation and measurement equipment it will be advisable to set up a small Instrumentation laboratory with the necessary equipment to calibrate, service and maintain the operational efficiency of the servohydraulic test systems and associated instrumentation. The Instrumentation laboratory should contain basic electronic workshop equipment. Also a frequency response analyser would be particularly useful instrument to have available for checking the dynamic response of equipment.

D. Computer Requirements

Computers are a very important requirement for a modern materials and component testing laboratory. The setting up of a computer section with engineers trained on the software and hardware aspects of digital computer systems may be considered as an essential requirement of the new fatigue testing laboratory. The computers will be required for both analytical work and experimental testing applications and an outline of these functions is given below.

(i) Automated Materials Testing System

It is recommended that Test Machine No. 1 be purchased complete with a minicomputer system and appropriate software. This would allow an immediate start to be made on the evaluation of monotonic and cyclic stress-strain properties of materials. Also, the determination of fatigue strength data in the form of strain life curves and the carrying out of Neuber control testing i.e. the simulation of the local stress-strain behaviour at a notch or stress concentration using a smooth materials test specimen would also be possible. Software is also available for carrying out strain controlled high temperature testing, fracture mechanics testing etc. and by means of extra hardware interfacing equipment this initial mini-computer system may be also used with one of the higher load capacity test machines.

(ii) Analytical Applications

In view of the volume and programme of work to be undertaken in the new testing laboratory a second computer system devoted to such topics as signal analysis and generation, fatigue life predictions and general software programme development would be desirable. The use of this system for on-line control of component fatigue tests would also be possible. Consideration should also be given to the use of microprocessors for conducting simple pre-programmed tests.

The selection of computers to undertake the above work will be very much dependent on the manufacturer selected to supply the servohydraulic test systems as either the Digital Electronics Corporation PDP 11/04 and PDP 11/34 computers or similar computer systems manufactured by General Automation Inc. will be supplied.

5. STAFF REQUIREMENTS

Staffing of the new fatigue testing laboratory will be dependent on the nature and volume of materials research work and component testing applications that are required to be carried out. As the intended programme of work will include such topics as low cycle fatigue, fatigue creep interaction, environmental fatigue, fracture mechanics and both metals and non-metallic materials will be investigated then it is expected that 5 or 6 engineers specializing in these fields of work may be employed.

The computer section will require 2 or 3 engineers and instrumentation, including strain gauging and service data acquisition, will also require 2 or 3 engineers.

For component testing work, including hydraulics and mechanical test fixtures, 2 engineers would be required. A number of junior engineers to support this staff will be required.

Thus an estimate of the number and distribution of staff would be as follows.

Testing applications	- 5 or 6 Engineers,	12 Junior Engineers
Computer section	- 2 or 3 "	3 "
Instrumentation section	- 2 or 3 "	3 "
Hydraulics, test fixtures design	- 2 "	2 "
	11 to 14 "	20 "

6. CONDUCTING REMARKS

As a result of visiting various research institutes and manufacturers and having technical discussions with a large number of engineers the following conclusions were reached.

(1) There is a considerable proportion of the present work devoted to fundamental studies on various factors which influence the fatigue strength of materials. In the long term the results of this work should prove beneficial.

(2) There is a considerable lack, however, of basic data that would be of immediate use to the engineering designer both in the selection of materials for specific engineering applications and in the estimation of the probable service life of new designs.

(3) The lack of appropriate data is a serious handicap in designing efficient and reliable machinery products and basically arises from a lack of modern test machines, instrumentation equipment and digital computers.

(4) The establishment of a centralized materials fatigue testing laboratory equipped with modern fatigue testing technology would be an appropriate first step in remedying this situation.

7. RECOMMENDATIONS

In carrying out the duties of this mission, as described in the Job Description, consideration was given to the fact that a further period of 3 months has been allocated (Ref. DP/CPR/79/021/11-06) to further UNIDO technical assistance on the subject of materials testing and fatigue. Priority was given therefore, in this initial 3 month period, to examining the present level of materials testing technology and to determining the basic equipment requirements for a new materials testing laboratory appropriate to local needs.

There is an undoubted and urgent requirement to establish a new laboratory on the scale suggested in this report and it is strongly recommended to the officials of the First Ministry of Machine Building Industry to give a high priority to this requirement.

It is recommended that further UNIDO technical assistance be directed to:

(1) technical guidance in the important decision regarding the final selection and purchase of the new test equipment.

(2) technical training of engineers on the use and application of modern fatigue testing technology particularly on the use of computerized test systems.

In view of the importance of this particular field of work, basic to the efficient design of a wide range of engineering products, it is further recommended that UNIDO give strong consideration to providing direct financial assistance in view of the very high capital expenditure required to establish a new materials testing laboratory on the scale envisaged in this report.

8. ACKNOWLEDGEMENTS

I would like to convey my sincere thanks to all the officials and engineers at the various Research Institutes and factories for their kindness, hospitality and support in carrying out this mission. In particular, I wish to thank the staff of the Shanghai Materials Research Institute, Deputy Director Mr. Gui Lifeng, Engineers Mr. Wang Jue, Mr. Ling, Mr. Cheng, Mr. Shang, for their technical assistance in completing this report and to my interpreter, Miss Wu Zhen Yun, for her very able assistance throughout the period of this mission.

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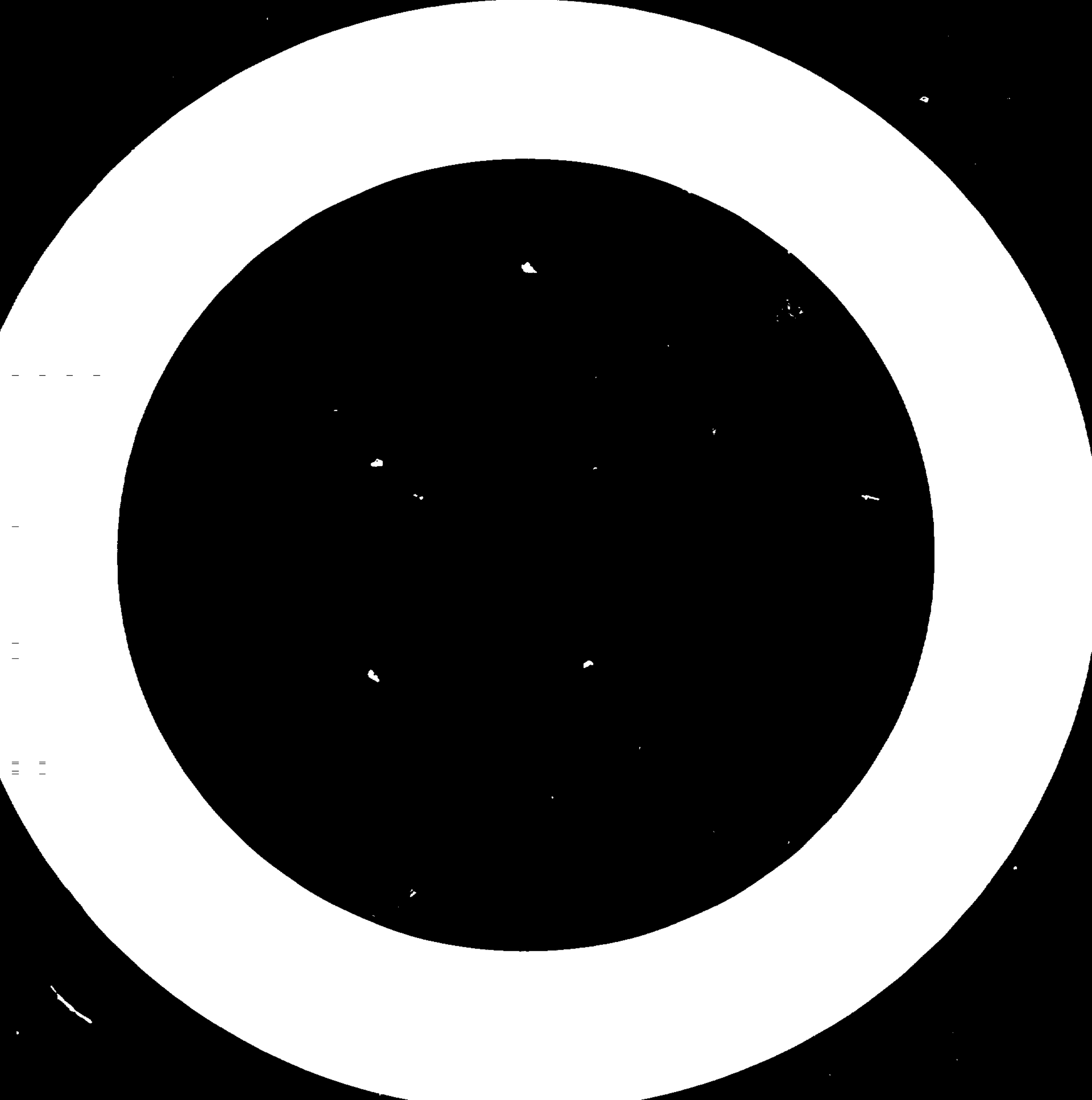


UNITED NATIONS

APPENDIX - 1

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

13 June 1980

PROJECT IN THE PEOPLE'S REPUBLIC OF CHINA

INTERNAL

JOB DESCRIPTION

DP/CPR/79/021/11-05/31.9.B. and
DP/CPR/79/021/11-06/31.9.B.

Post title: Expert in Materials Testing

Duration: 2 x Three Months

Date required: As soon as possible

Duty station: Shanghai

Purpose of project: To assist the country in strengthening its machinery building industry. This will help to increase the productivity in the agricultural sector and thereby avoid a diverting of resources from the industrialization programmes to provide measures to help feed the population adequately.

Duties: The expert will be attached to the First Ministry of Machine Building and specifically will be expected to:

(1) Assist in establishing and equipping of a centralized materials testing laboratory.

(2) Provide technical guidance in the field of design and development of tools for metal fatigue technology and metal fatigue testing.

(3) Train local specialists in metal fatigue technology and metal fatigue testing.

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

..../..

Qualifications High-level expert familiar with the current state-of-the-art in metal fatigue technology and testing.

Language English

Background information The world's largest country, China, has continually faced the problem of stimulating and achieving a steady rate of industrial growth. As with any developing country the establishment of a sound industrial base is important and a goal that deserves particular attention.

Prior to the revolution of the late 1940's China's industrial base was limited to a narrow range of manufacturing plants. These plants were located principally in the coastal provinces with a few located near the inland river parts. Almost 75 per cent of all factories, non-agricultural workers, industrial equipment and energy consumed were confined to areas in and around Shanghai and Tientsin.

After the revolution an attempt was made to allocate industrial resources more evenly throughout the country. Goals for accelerating the rate of industrilization were set. However, the staggering task of repairing the damage resulting from World War II absorbed the major portion of China's resources and resulted in a failure to meet these goals.

The picture during the last half of the 1960's is not clear due to a lack of adequate documentation. However, it appears that the industrialization growth rate declined. In spite of the progress that was made (even through some of it was sporadic), China was far from being an industrialized country. Although there was definite and significant growth, it failed to approach the desired goals for a variety of reasons:

- Political problems resulted in idle productive capacity that also fell into a poor state of maintenance;
- A decline in labour productivity resulting from heavy capital reinvestment at the expense of wage increases;
- Misallocated capital investment as a result of poor planning;
- The necessity to divert available resources into agriculture to feed the rapidly increasing population;
- The earthquake in Hopei Province.

Data available in 1977 indicate that China has identified and analyzed these problems and their derivative problems and developed an appropriate Plan of Action to achieve its goal for increasing its industrial growth rate.

NO CANDIDATES REQUIRED AT THIS TIME

APPENDIX - 2

THE ORGANIZATIONS UNDER THE INSTITUTE OF
MACHINERY SCIENCE AND TECHNOLOGY

1. Shanghai Research Institute of Materials
2. Zhengzhou Research Institute of Mechanical Engineering
3. Research Institute of Mechanical and Electrical Technology
4. Research Institute of Automation for Machine Building Industry
5. Haerbin Research Institute of Welding
6. Shenyang Research Institute of Foundry
7. Wuhan Research Institute of Material Protection
8. Standardization Research Institute

Visits to the first four institutes and to the following factories were carried out:

Shanghai Gas and Steam Turbine Factory

Shanghai Boiler Factory

Shanghai Jiao Tong University

Shanghai No. 5 Iron and Steel Works

Nanjing Automobile Factory

Research Institute of the Nanjing Turbine and Electrical Machinery Works

Area of work of the eight institutes under the Institute of Machine Science and Technology:

1. Haerbin Research Institute of Welding

   There are laboratories of welding technology, welding materials, welding equipments and welding structure etc..

2. Shenyang Research Institute of Foundry

   There are laboratories of cast steel, cast iron, special foundry technology, moulding materials, sand moulding casting and foundry equipments and instruments.

3. Wuhan Research Institute of Material Protection

There are laboratories of electro-chemistry, anti-rust, metal corrosion, heat treatment, spray coating and friction and wear. etc..

4. Research Institute of Automation for Machine Building Industry

There are laboratories of system engineering, automatic detection and monitoring system, nuclear accelerator, application of superconductor, hydraulic and pneumatic device, micro-machine mechanical hand, transmission unit and hydraulic vibration technique and equipments etc..

5. Research Institute of Mechanical and Electrical Technology

There are laboratories of forging, heat treatment, non-destructive testing and die lubrication etc..

6. Standardization Research Institute

There are laboratories of basic standard, mechanical product standard, electric meters and instruments standard and international standard.

7.. Zhengzhou Research Institute of Mechanical Engineering.

A. Mechanical Strength Laboratory

(i) Group of mechanical structure stress analysis
Carrying out the stress analysis of mechanical parts and components by means of electric measurement, photo elasticity and laser.

(ii) Group of calculation and the general purpose programme
Calculating the stress, strain and displacement of the parts and components under the certain service condition, and coding programme.

(iii) Group of fatigue fracture
Carrying out the fatigue strength testing of the parts and components and their life evaluation. Evaluating the allowance stress and residual life of the parts and components with defects and cracks from the view of the fracture mechanics.

(iv) Group of mechanical vibration
Carrying out the balance testing of turbines and steel rolling machines etc.

B. Gear Laboratory

C. Foundry Technology Laboratory

D. Welding Technology Laboratory

E. Forging and Heat Treatment Technology Laboratory

F. Chemical Analysis Laboratory

G. Meters and Instruments Laboratory.

8. Shanghai Materials Research Institute

Department 1 - Material Strength

In order to optimize the selection and application of materials, Department 1 investigates strength, fatigue and creep at high temperature; fatigue and brittle fracture at low temperature; and fatigue at ambient temperature. It also studies the mechanism of various modes of failure by macro- and micro-methods, and develops appropriate new alloys for certain special purposes.

Department 2 - Non-destructive Testing

Department 2 investigates and develops the principles, methods and techniques of non-destructive testing, as well as some special instruments and equipments concerned. The testing methods adopted include those by ultrasonics, eddy current, radiography, magnetic powder and liquid penetration.

Department 3 - Physical Testing

This department devotes itself to testing various physical properties of materials, developing new testing methods, investigating various modes of failure by means of micro methods and placing emphasis on fracture analysis. The area of its activity involves optical metallography, electron microscopy, X-ray diffraction analysis, etc.

Department 4 - Chemical Analysis

Department 4 is engaged in the chemical analysis of materials, including ordinary, micro and automatic analysis, as well as in the research of new analytical methods. Its activities include wet chemical analysis, emission spectrography, atomic absorption spectrography, polarography, X-ray fluorescence analysis, etc.

Department 5 - Non-metallic Materials

Department 5 investigates technology and testing methods of fibre-reinforced composites with high module and high strength, and the related mechanism. At the same time, it studies the techniques of composing the non-metallic or metallic fibres or grains with high polymers, and works on the common problems with respect to the application of engineering plastics in the areas of anti-friction, sealing, self-lubrication and water-lubrication.

Department 6 - Technology of Metallic Materials

Concerning the processes of smelting, casting, forging and welding, Department 6 further improves the properties of the existing materials, specifies the manufacturing processes of new materials, and tests the technological properties of metallic materials.

Department 7 - Powder Metallurgy

Department 7 investigates the high-temperature, dispersion-strengthened alloys prepared by mechanical alloying method, the special cement carbides used for tools and dies, and the powder preparing techniques.

Department 8 - Application of Radio-isotopes

This department researches the industrial applications of radio-isotopes: studying the phenomena of friction and wear, determining the contents of various elements by X-ray fluorescence methods with low energy radiation, and analyzing the crystal structure and defects by means of Mössbauer effect.

Department 9 - Corrosion of Metals

Department 9 investigates the testing methods, mechanism and protection of localized corrosion (including stress corrosion, pitting corrosion and crevice corrosion), hot corrosion, corrosion fatigue, etc., studies passive films on the surfaces of metallic materials and develops the new materials with high resistance to localized corrosion.

Department 10 - Wear-resistant Materials

Department 10 carries out the investigation of the wear-resistant metals, the best matching of friction pairs, the testing methods for adhesive and abrasive wear, the mechanism of wear as well as the protective measures.

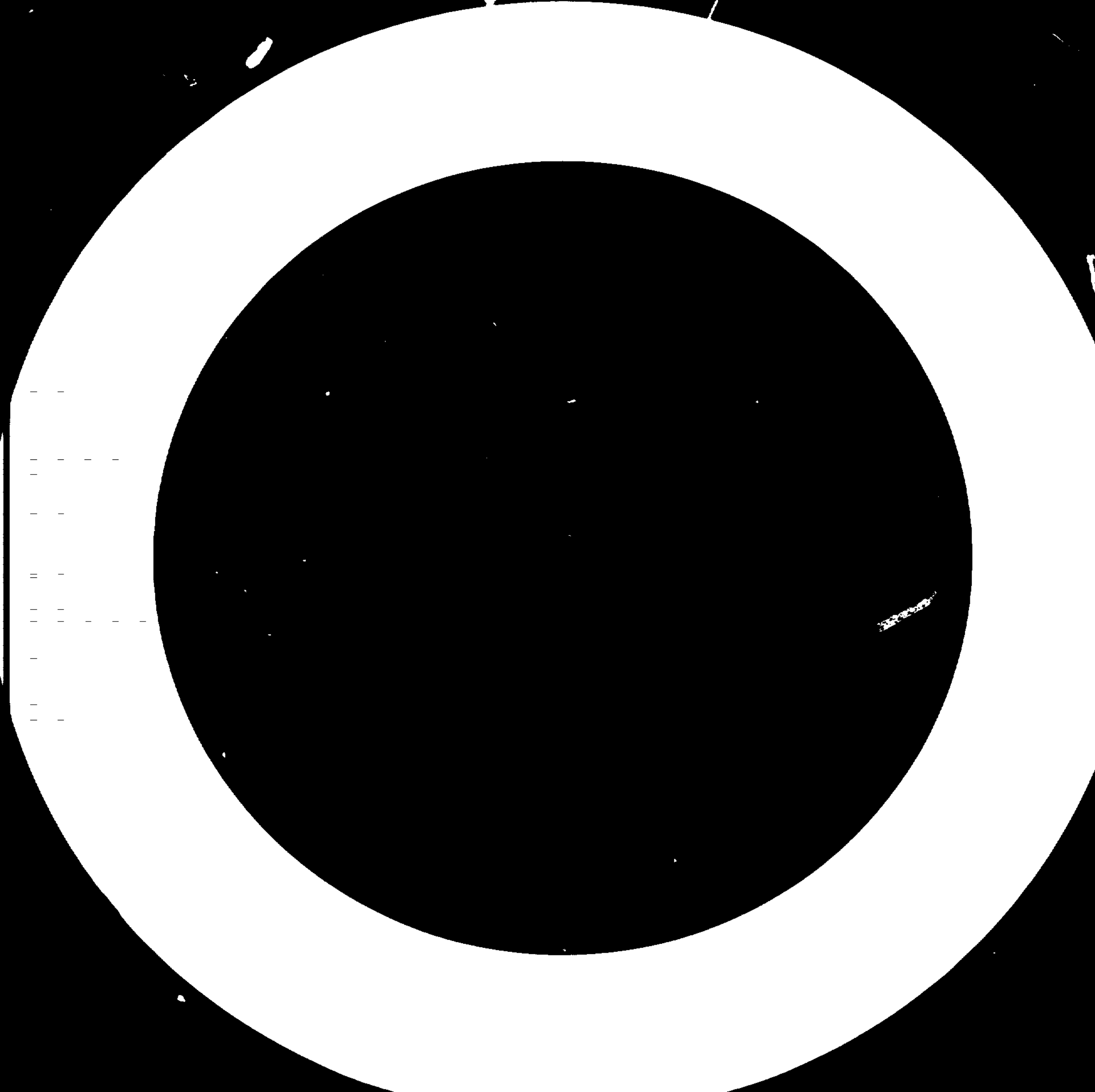
This department also deals with the processes and mechanism of strengthening and toughening of components in order to exploit the potential availability of materials, and optimizes the selection and application of materials, especially for wear-resistant use.

Department 11 - Technical Information

Department 11 masters and analyzes the developing trends both at home and abroad, publishes periodicals, manages technical reference materials and translates the foreign literatures. It also attempts to further develop the techniques for selecting materials and accumulating the data concerning the material properties by electronic computer.

Department 12 - Comprehensive Workshop

The Comprehensive Workshop is engaged in making samples, designing and manufacturing special equipments, and undertaking maintenance routine.



WORKING PROGRAMME FOR EXPERT A. J. MORRISON OF UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

According to the United Nations Development Programme and the document of the First Ministry of Machine Building Industry, we think that the material fatigue testing laboratory may carry out fatigue testing of various materials, and simulation test cf some components and assembly under actual working condition. It will be equipped with modern experimental techniques and facilities. The measuring controlling and data treating should be automatized and computerized as much as possible.

A. Tasks of Material Fatigue Testing Laboratory

Mainly research fatigue or iron and steel, also engineering plastics, composites and some non-ferrous metals, and solve certain problems of power plant equipments, pressure vessels, automobiles and equipments of sea drilling, such as the low cycle fatigue, fatigue-creep interaction and the effects of random load, temperature, medium and environment on fatigue properties.

B. Working Steps

1. Exchanging information each other

First of all, we will detail our purposes and demands for design of material fatigue testing laboratory and introduce the fatigue research work of our country and main equipments used at present. Then expert A.J. Morrison would give us a brief introduction of the testing technology and testing methods of the material fatigue in the world now. The emphasis will be on the research work of material fatigue, as well as the scale and equipments of the laboratory in NEL. Through exchanging information, both of us may have a good knowledge.

2. Visiting, Lecture and Discussion

Expert A.J. Morrison will be arranged to visit some typical power plant equipment manufactories, automobile manufacturers and fatigue testing laboratories concerned, especially that of Shanghai, so that expert A.J. Morrison can know more about the present condition of mechanical industry of our country, and well design a material fatigue testing laboratory, which is suitable to the actual condition of our country. At the same time, expert A.J. Morrison will give us some lectures and have discussions.

The following topics for the lectures will be selected at will:

1) the testing technology and developing trend of the material fatigue in the world.

2) the expressing methods of the testing results and the methods of data treatment.

3) the experimental technology and actual significance of the low cycle fatigue and creep-fatigue interaction.

4) the development trend of testing equipments, detection technology and monitoring technology.

5) the experimental technology and actual significance of programme fatigue and random fatigue.

6) the estimating methods of fatigue life (including residual life).

7) the effects of combined stress, temperature, medium and environment on fatigue properties.

8) Application of fatigue to engineering design and mechanical products.

3. According to our demands and your experiences, expert A.J. Morrison would design a material fatigue testing laboratory which can serve to design modernized machines and the optimum selection of materials. The contents of design include defining the scale of laboratory, drawing up a list of main equipments, supplementary equipments, attachments and spare parts, laying out the plan of equipments and estimating the total investment and working people required.

4. A summary report will be written by expert A.J. Morrison to UNIDO. We hope that the material fatigue testing laboratory will be considered as a special financial assist item by UNIDO.

C. <u>Working Arrangement of Two Months and Two Weeks</u>

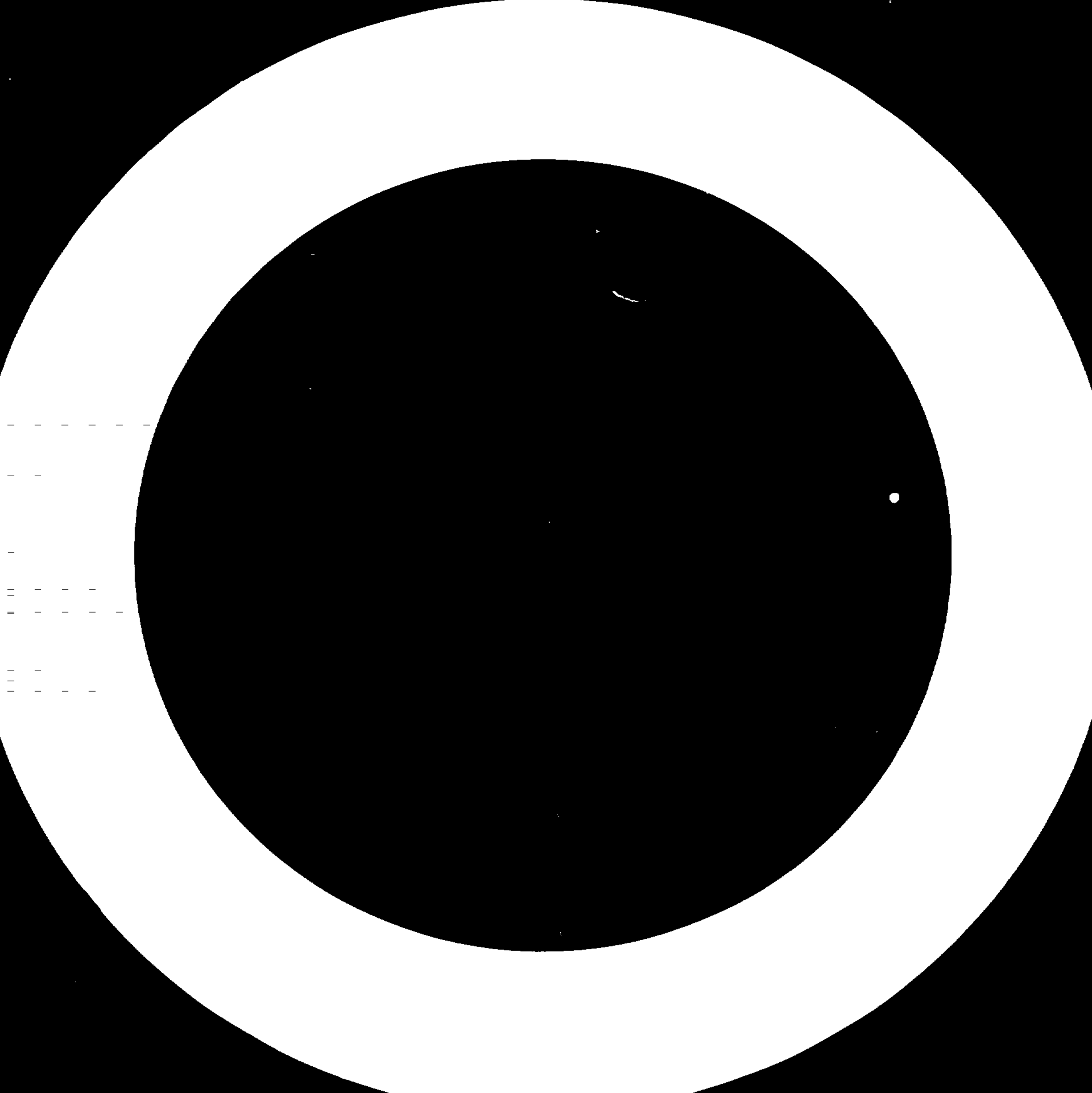
1. Exchanging information each other, visiting, lectures and discussions 4 weeks

2. Design of material fatigue testing laboratory 5 weeks

3. Writting a summary report 1 week

D. <u>Working Place</u>

In Shanghai Research Institute of Materials.



TECHNICAL DISCUSSION SESSIONS

SHANGHAI SCIENCE HALL

SESSION No. 1

Question 1: What main fatigue testing machine should a steam and gas turbine plant have?

2. Statistical analysis of fatigue data.

3. Relationship between pure rotating bending fatigue data and tension-compression data.

4. Effect of wet and semi-wet steam on the fatigue patigue properties of materials and its mechanisms.

5. The effect of cavitation on the fatigue strength of gas turbine blades and hydraulic pump blades.

6. How to allow for fatigue in the design of boilers and describe high temperature low cycle fatigue testing techniques?

7. How to treat the low cycle fatigue problems in designing pressure vessels? What criteria are important and can the fatigue behaviour of the component be represented by a small material test specimen?

8. The inlet pipe of a power station boiler of capacity 400 tons of steam per hour cracked at a weld after 10,000 hours. Is the failure due to fatigue? Is it possible to carry out a simulation test on the pipe? The pipe temperature is 550°C.

9. Describe test facilities and techniques for crack propagation studies. What crack measuring techniques are used in the United Kingdom?

10. Analysis methods for random signals.

11. Measurements and dynamic calibration of fatigue testing machines.

SESSION No. 2

Question 1: Detailed introduction to road vehicle simulation testing.

2. Introduction to the sequence of steps in the design process of a new vehicle. Describe the relationship between the design department and the testing department.

3. The use of the Amsler Vibrophore machine for the testing of components and the modification of the machine for carrying out narrow band random testing.

4. The fatigue testing of a vehicle chassis frame and the testing of a commercial vehicle cab.

5. Introduction to the Rainflow method of cycle counting.

SESSION No. 3

Question 1: Typical frequency response of servo-hydraulic actuators.

2. Electromagnectic vibrators.

3. Electronic instruments for the analysis of service loads.

4. As fatigue results are dispersive how many samples require to be tested?

5. Does Miner's law apply to all metals?

6. How to consider fatigue on the design of an oil platform for use in the North Sea?

7. General structural welding fatigue problems.

8. Effect of overloads on fatigue life.

9. How to measure the plastic strain peak in a material?

10. In a simulation fatigue test of a component using a small test specimen is the fatigue strength of the specimen similar to the component?

11. How to use the results of random vibration analysis techniques such as autocorrelation, power spectral density etc.?

12. How to relate random vibration analysis to cumulative damage assessments?

SESSION No. 4

Question 1: Illustrative example to show the use of the Rainflow method in carrying out fatigue life predictions.

2. How to measure the true stress-strain curve for a material?

3. Under compression cyclic loading do the cracks and cavitation flaws in welds propagate?

ZHENGZHOU RESEARCH INSTITUTE OF MECHANICAL ENGINEERING

GROUP DISCUSSION TOPICS

1. What fatigue designing methods have been used in U.K.? (For example, whether the static strength designing method is first used and then checked by fatigue strength, or the fatigue designing method is directly used) when we design a machine bearing a dynamic load?

2. How to improve the outdated fatigue testing machines (which can only work under constant-amplitude and constant-loading conditions) in order to carry out random fatigue and programme control fatigue tests?

3. What simulation methods have been used in testing? Whether does the local strain simulation method find application? Whether does this method only consider the maximum strain at the stress concentration area, but not consider the stress condition and strain gradient? Is this consideration correct?

4. What factors should be considered when we use material fatigue data in strength designing of machine parts? In designing procedure, how to consider the effects ofdimension factor, effective stress concentration, surface condition and average stress on the fatigue strength of machine parts?

5. What are the factors which influence dimension effect? Which one is the dominant factor?

6. How to consider the safety factor when we do the fatigue designing of machine parts? Has the reliability theory been used in selecting the safety factor in the U.K.?

TITLES OF FORUM DISCUSSIONS

1. Present condition and developing tendency of fatigue testing technique and methods of machine parts in the world.

2. Testing technique and data processing of programme fatigue and random fatigue. Please illustrate how to use test data to evaluate life of machine parts.

3. What fatigue tests have been carried out in NEL? How to use these test data to evaluate the strength and life of machine parts?

4. What is your opinion on carrying out mechanical strength research work in our institute?

NANKING AUTOMOBILE FACTORY

1. How to use the programme control fatigue test to simulate the automobile road test?

2. Accelerated methods of the machine parts fatigue test and their equivalent relation.

3. What are the methods which can be used to do the bending fatigue test of the crank sharft of the gasoline and diesel engines? What are the differences of the test methods? Calculating methods of the crank sharft bending stress.

4. How to deal with the excess allowance (about 40%) due to the fixture's weight when we do the four points bending fatigue test of sheet, of which the thickness is less than 5 mm on the AMSLER 10HPP 1478 test machine?

5. Calibration methods of the dynamic load on the high frequency fatigue test machine.

6. How to determine the bending fatigue test load on the driving and passive gear sets of rear axle housing? How to evaluate the test results?

7. The amount of load is determined by the amplitude during assembly test on the springs in some factories at present. We do not think this method is reasonable. What is the situation abroad? How to determine the frequency of spring test?

8. How to calculate the maximum stress of compression - compression fatigue of piston pin?

9. What are the requirements of the selection of fatigue test sample?

10. Statistic processing methods on the fatigue life test data.

NANJING TURBINE AND ELECTRICAL MACHINERY WORKS

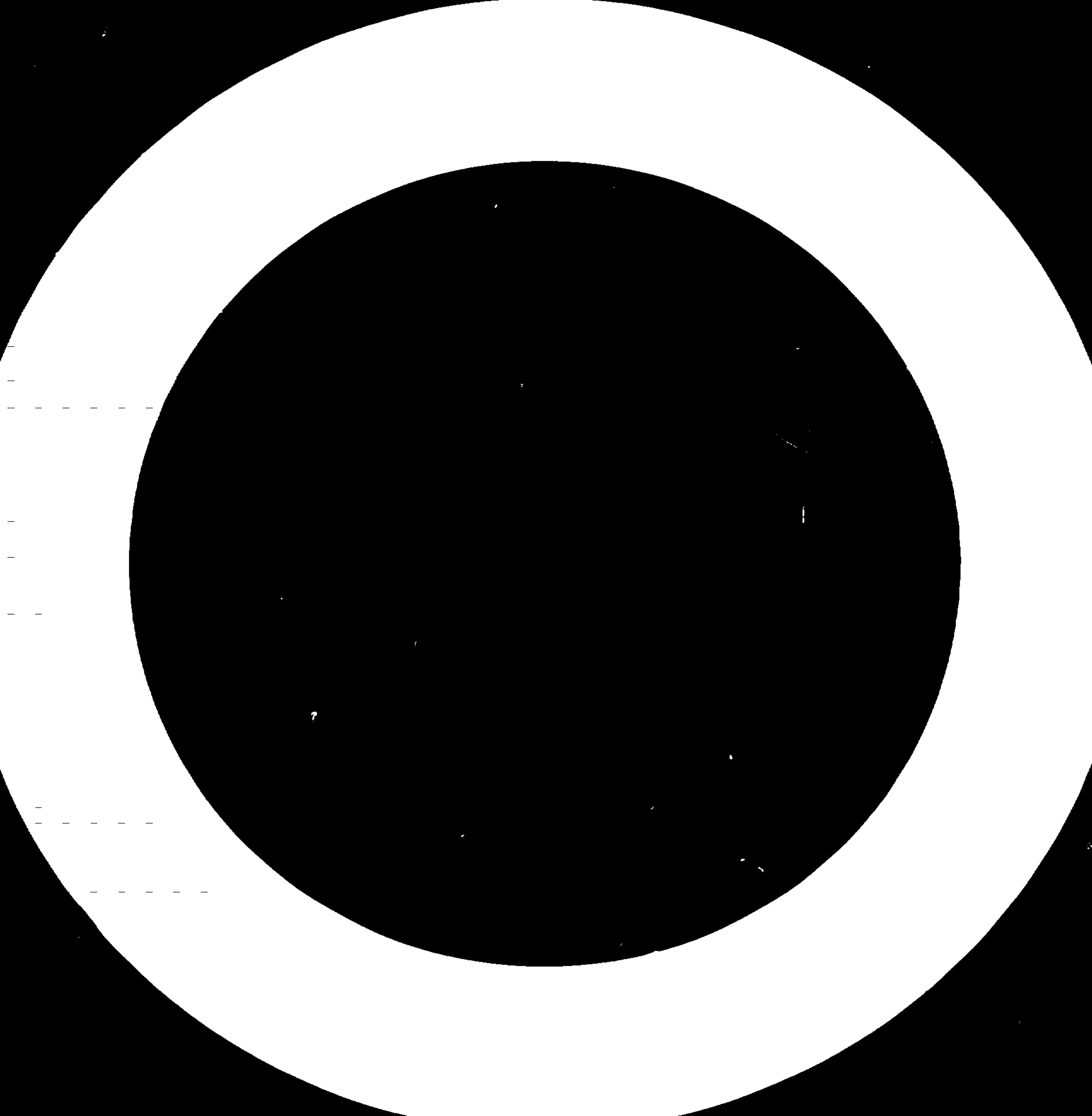
1. What are the main subjects of fatigue research in gas turbine manufactories abroad? How to combine the product design with the fatigue research?

2. Aspect of low cycle fatigue research abroad. Research progress of crack propagation rate during low cycle fatigue and thermal fatigue test.

3. How to carry out fatigue research from point of view of material?

4. General introduction to fatigue test machines abroad.

5. Research situation of retardation effect of fatigue crack caused by overload.



APPENDIX - 5

SPECIFICATION OF SERVOHYDRAULIC TEST MACHINES AND ACCESSORIES

1. Test Machine

TEST MACHINE NO.	STATIC LOAD CAPACITY R N (Ton)	TOTAL STROKE mm (INS)	SERVOVALVE SIZE 1 m/m (CPM)	REMARKS
1.	50 (5.0)	100 (4.0)	136 (30.0)	High response basic materials test system
2.	250 (25.0)	100 (4.0)	272 (60.0)	Materials and components testing
3.	250 (25.0)	100 (4.0)	272 (60.0)	Specification same as test machine No. 2.
4.	500 (50.0)	150 (6.0)	272 (60.0)	Materials and components testing
5.	1000 (100.0)	150 (6.0)	544 (120.0)	Materials and components 2 x 272 l/min. servo valves in parallel.

2. Accessories

GRIPS and Test Fixtures

For test machine No. 1 it is recommended that self-aligning cast metal grips be obtained.

For test machines Nos. 2 and 5 hydraulically operated grips are preferred. Fracture mechanics grips and bending test fixture will also be required.

Extensiometers

As a wide variety of extensiometers are available of the axial and diametral type, to suit a range of different gauge lengths, strain ranges and temperature conditions it is difficult to specify the most suitable types until the test specimen geometry and test conditions have been defined.

For test machine Nos. 1 and 2 axial, high temperature extensiometers with self-contained transducer conditioning unit for the direct control of strain will be required.

For fracture mechanics testing clip on gauges for crack opening displacement will be required.

High Temperature Furnace

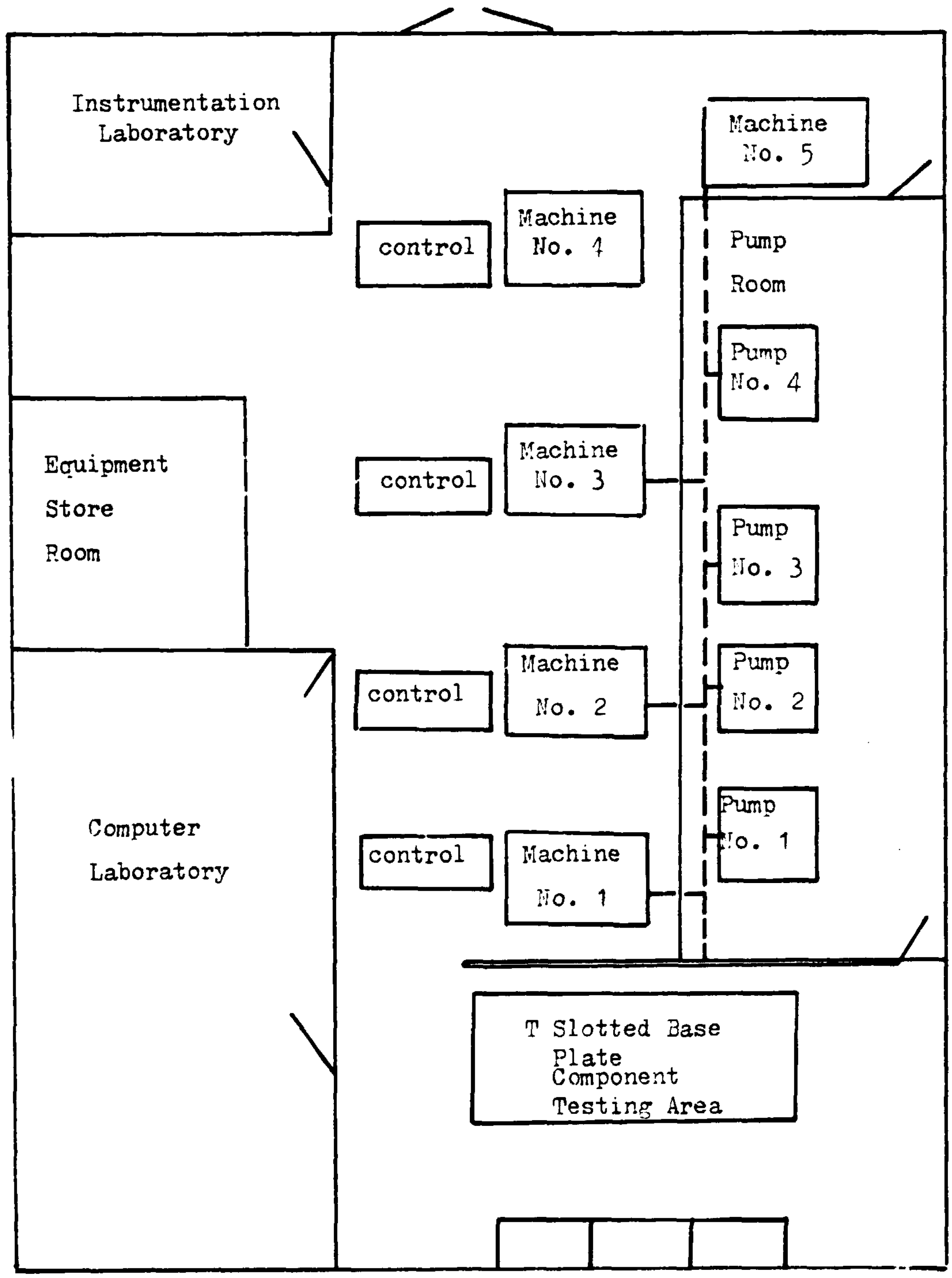
For test machines Nos. 1 and 2 a high temperature furnace to allow the testing of specimens up to 900^{o} will be necessary.

Environmental Chamber

An environmental chamber for carrying out the testing of specimens under salt spray conditions will also be required.

Possible Layout of Fatigue Testing Laboratory

Scale 1:100 (To Fit Existing Floor Plan)



COST ESTIMATE FOR NEW EQUIPMENT

Unfortunately it was not possible, in the time available, to write a specification of the new laboratory equipment requirements and submit it to potential suppliers to obtain an up-to-date estimate of the costs.

A very approximate figure can therefore only be given based on the limited information available at this time.

Test machines (basic cost, no hydraulics or grips etc.)

Machine No. 1 - approximate cost	90,000	yuan
No. 2 - " "	125,000	"
No. 3 - " "	125,000	"
No. 4 - " "	175,000	"
No. 5 - " "	210,000	"
Total	725,000	yuan

Component testing actuators plus control equipment

6 - servohydraulic actuators plus servovalves and load cells	approximate cost	220,000	yuan
6 - control channels	" "	300,000	"
	Total	520,000	

Hydraulic pumps and ring main installation

4 - Hydraulic pumping units	approximate cost	150,000
Hydraulic ring main installation	" "	110,000
		260,000

Computer systems

Hardware plus software programmes	450,000

Additional instrumentation equipment

Measurement and test equipment	175,000

Accessories

Grips, furnaces, extensiometers etc.	150,000

Total estimated cost = 2,280,000 yuan

POSSIBLE SUPPLIERS AND SERVOHYDRAULIC EQUIPMENT AND INSTRUMENTATION

1. MTS Systems Corporation
   P.O. Box 24012
   Minneapolis
   Minnesota 55424
   USA

2. Carl Schenck AG
   Postfach 4018 D 6100 Darmstadt 1
   West Germany

3. Servotest Limited
   Servotest Works
   14 Aintree Road
   Greenford
   Middlesex UB6 7AA
   England
   UK

4. Instrom Limited
   Coronation Road
   High Wycombe
   Bucks HP12 3SY
   England
   UK

5. Dartee Limited
   Mill Race Lane
   Stourbridge
   West Midlands DY8 IHU
   England
   UK

Instrumentation Supplies

1. Solartron Electronic Group Ltd.
   Farnborough
   Hampshire
   England
   UK

2. Hewlett Packard Ltd.

Computer Software

(Signal analysis and fatigue life prediction)

SDRC. Engineering Services (UK/Scan) Limited
York House
Stevenage Road
Hitchin
Hertfordshire SG4 9DY
England
UK