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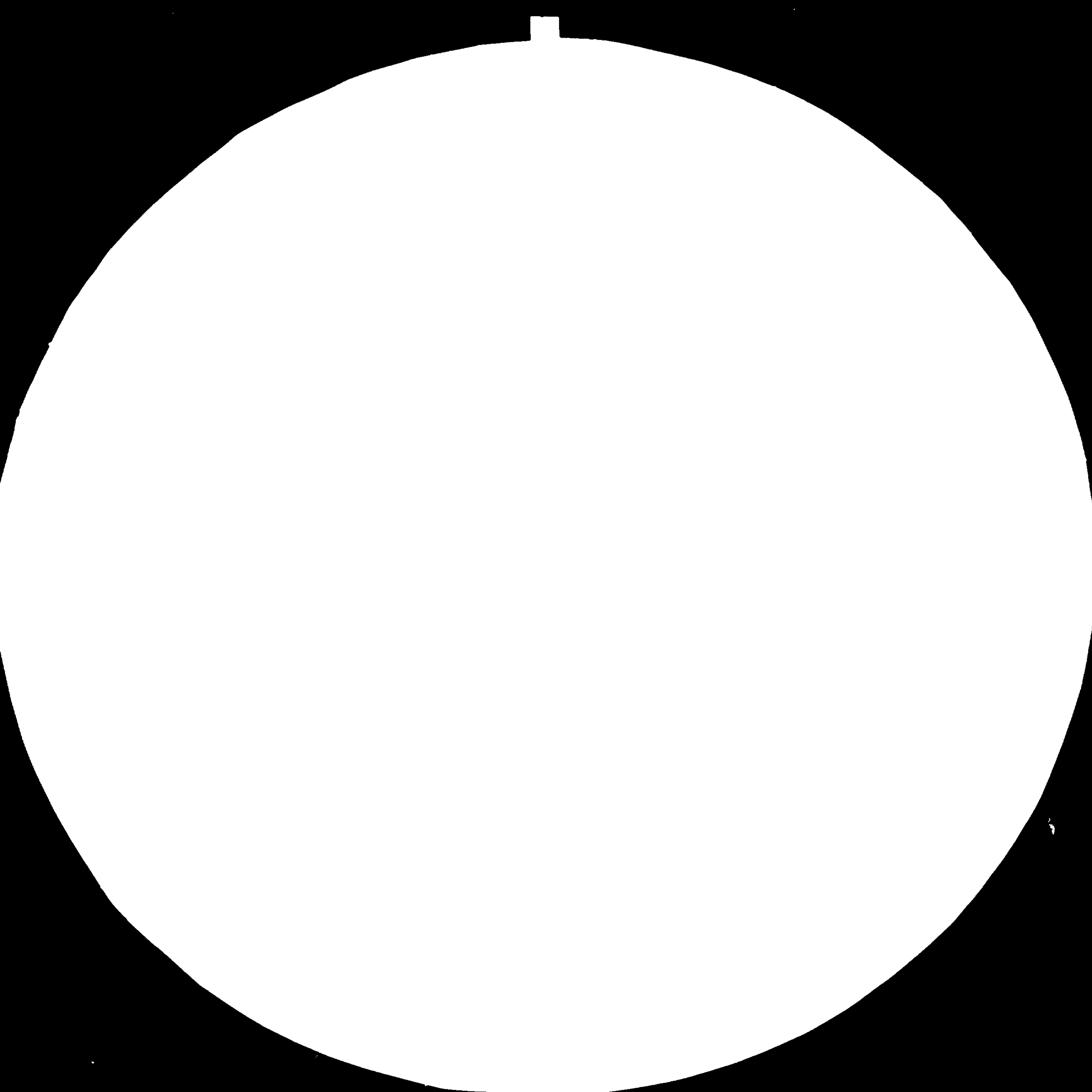
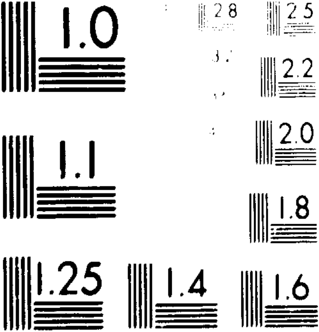
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org





MICROCOPY RESOLUTION TEST CHART

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18 October 1983
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ASSISTANCE TO MACHINERY BUILDING INDUSTRY

DP/CPR/79/021

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 W. R. Keeble,
expert in the design of tractors

United Nations Industrial Development Organization
Vienna

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EXPLANATORY NOTES

ECE	-	Economic Commission for Europe
LTRI	-	The Luoyang Tractor Research Institute
NIAE	-	National Institute of Agricultural Engineering
OECD	-	Organization for Economic Co-operation and Development
PTO	-	Power Take Off
UNDP	-	United Nations Development Programme
UNIDO	-	United Nations Industrial Development Organization
4WD	-	Four Wheel Drive

ABSTRACT

PROJECT: DP/CPR/79/021/11-19/31.9.B

As a part of the United Nations Development Programme, an expert in the design of tractors was sent by UNIDO, executing agency, to the Luoyang Tractor Research Institute of China in the Henan province of the People's Republic of China.

The purpose of the project was to assist the country in strengthening the agricultural sector of its machine building industry, improving its tractor design and the efficiency with which they are developed, tested and manufactured.

The three months mission was carried out from 29 June 1983 to 28 September 1983 at Luoyang, apart from a 14 days field trip to observe paddy tractor trials and visit tractor factories in the South of China.

Lectures were delivered to selected specialists from the Institute research departments.

Lectures covered all aspects of management, tractor design and development with emphasis on specific test procedures and criteria.

The expert also took part in design review of all major features of the new proposed 65 HP paddy field tractor.

Factory visits were made and recommendations were noted by management for further consideration and action.

From the lectures, the test criteria given and the design review, modern technology has been offered to the Institute for improving its tractor design and testing.

From test results the necessary design changes can be made to attain the objectives set for tractor performance. Only test results can confirm the achievement of the tractor objectives. Durability of the new tractor series will be secured if new equipment is procured to establish a fatigue laboratory. Existing facilities are more effectively used and appropriate training arranged.

CONTENTS

INTRODUCTION

One third of China's 100,000,000 hectares of arable land are used for paddy field cultivation.

Rice production is scattered throughout the country. With the different farming systems and rice croping time scales, various types and sizes of paddy field tractors are needed.

In the 1950s lightweight tractors were imported for paddy field use. They had serious shortcomings since it was not their original intended design purpose.

China started to develop its own agricultural tractors in 1955. Since then a very diversed range has grown.

Tractors are now produced in all provinces and models are mainly tailored for the local conditions.

From this profusion of models, a new design to form a basic range of paddy field tractors in the 35-65 HP class was started in 1975.

The first phase of new paddy tractor series was designed and successfully tested by the end of 1980. the second phase of final acceptance tractors is at the completion of design with prototypes available for testing at the end of 1983.

Assistance to confirm tractor design and advise on testing programmes are requested from the United Nations Development Programme (UNDP).

The United Nations Industrial Development Organization (UNIDO) as the executing agency of project DP/CPR/79/021/11-10/31.9.B. in co-operation with the Ministry of the Machine Building Industry, appointed the first expert from 29 June 1983 to 28 September 1983 (the subject of this report) to work at the Luoyang Tractor Research Institute of China (LTRI). All objectives as stated by UNIDO were incorporated in a work programme developed at an early stage of the mission. It included:

1) A lecture series and design reviews of the proposed paddy field tractor, held at the LTRI.

2) Field trials in the rice paddy fields of the Jiangxi province.

3) **Factory visits and discussions in Nanchang, Hangzhou and Shanghai.**

At the completion of the mission a sound basis had been formed for the new design to proceed through final design and testing in order to achieve the targets set for performance and reliability.

I. RECOMMENDATIONS

1. The Institute must quickly develop a fatigue laboratory. Basic equipment as discribed should be provided with a supporting stress coating facility.

2. Consideration should be given to provide a 2ND expert after commissioning of the fatigue laboratory. This expert would give training and instruction, using computer facilities, on methods of determining life from the analysis of accumulated fatigue data.

3. The Institute must develop capability to determine and record accurate field loads and histories as the basis of Laboratory tests.

4. The computer facility must be upgraded or completely renewed to store and analyse the Institute's data bank.

5. The Institute should pay more attention to researching human factors of cabs, etc., to catch up with the world tractor level in this area.

6. The Institute should accelerate the usage of its existing facility to progressively formulate a series of tests and correlated criteria to serve as a basis for testing throughout China.

7. The Institute must improve management to control its design and test functions. Base documents must be formulated and used to ensure discipline through all stages of development.

8. Testing experience must be rapidly built within the Institute. Most of the engineers' time should be spent assisting in field and laboratory tests. Opportunities for engineers to gain immediate test experience at official oversea's test stations should be considered.

The NIAE at Silsoe England have ideal facilities and activities.

9. Full consideration should be given to the numerous suggestions made during this mission.

10. The Institute should forecast the technological deficiencies it will face in responding to its future business plans. Many of these can be strengthened from within China. Direct local training in Chinese is maybe of more general benefit. In specific sciences, where technology does not exist, further expert aid ought to be considered.

11. The manufacturing industry must update foundries producing low-grade castings. Production areas must pay more attention to the "protection of their stock" at all stages of manufacture, to produce quality tractors with acceptable appearance.

12. The possibility of UNDP/UNIDO assistance in financing the implementation of the above recommendations should be considered.

II. OBJECTIVE OF THE MISSION

A. Job description

Purpose of project:

To assist the country in strengthening its machine building industry by improving the quality of its products, the efficiency with which they are produced and the working conditions in industry. This will increase the rate at which the industrialization programmes can proceed and will also help to increase productivity in the agricultural sector.

Duties:

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

1. Give advice on methods and procedures for the design, development and testing of new types of tractors.

2. Assist in the evaluation of a prototype 35/65 HP tractor for use in rice fields and in making improvements of it.

3. Give advice on up-to-date methods of design for lightweight high-strength components, the reduction of noise, and the design of reliable hydraulic systems.

4. Give advice on the testing of component parts and on accelerated life tests for complete tractors.

5. Give advice on the equipment and training required for tractor research, design and testing.

6. Give lectures to an audience of about 40 engineers, drawn mainly from the Institute including some from factories.

7. Work with members of the staff in the Institute and also in field trails.

B. Work plan

An initial lecture schedule was planned for the first phase shortly after arrival and introduction to the Institute function and facility. The second phase was established after the completion of a 14-day field trip to observe tractor paddy field trials and factory visits. This second phase included an 11-day review of the proposed new paddy field tractor.

With a few insignificant changes, the work schedules were completed. They satisfied the project duties in all respects with the exception of some precise hydraulic design features, due to limitation of the expert, however a total understanding of hydraulic field behavior, testing techniques and hydraulic test criteria were transferred.

III. LECTURES

A. General

Lectures were carried out according to the work plan. In all, 18 lectures with discussion sessions were given from 8:30 to 11:30 a.m. During this period most afternoons were reserved for preparing the next day's lecture. All aspects of management, design and evaluation of components and total tractor were dealt with to satisfy the duties of the mission, slide presentations supported many of the lectures and three 20 minute movie films of tractor tests were shown.

Each audience was selected from specialists groups within the Institute, as appropriate to the lecture topic, numbers ranged from 35-10 people, technology transfer was more effective after the first few days with the audience gaining confidence to enter discussion.

One large audience lecture on "Agriculture in Europe" was delivered at the Jiangxi Tractor Factory in Nanchang.

B. Lecture main topics

Management

Lectures dealt with the need of a good managment "structure" to ensure efficient control and use of manpower and facilities from initial concept to production.

The following were the key subjects discussed:

- Organization charts showing the relationship of the engineering functions with other departments of market research and manufacturing, etc.
- Formulation of the project specification.
- Overall budget forecasting of project manpower, materials and facilities required.
- Timing charts showing specific dates for the design, deve-

lopment, acceptance and validation testing to production.

. Establishing design and test criteria to verify project objectives.
. Planning test sequence.
. Formats of control documents for engineering inspection, test instruction, and test reporting.
. The importance of design reviews to search and resolve problems.
. The progressive documentation of all achievements against objectives.

Design

Separate design lectures were delivered on all major features of the modern tractors.

In specific areas, when requested detail was more exactly examined, in some instances actual hardware was provided to enhance the discussion.

Discussion included:

. Modern trends of tractor features in Europe.
. New design techniques.
. Designing to meet legal requirements of safety, noise, smoke, speed etc.
. The concept and benefits of family design of engines transmissions, cabs, etc.

This last topic was of special interest since consideration to this concept is being given to the new paddy field tractor series.

Testing

This subject was dealt with at great length and detail, it is here the Institute is most vulnerable. It has very little laboratory testing experience, partially due to the lack of laboratory equipment. Testing formed the basis of most of the discussion at the completion of each lecture.

Main topics were:

. Detail of modern test equipment and facilities necessary to conduct accurate laboratory tests.

. Determination of field loads and histories.
. Procedures for conducting specific tests.
. Planning meaningful tests.
. Accelerated laboratory testing for components and tractors.
. Laboratory rig correlation.
. Tractor test track and field tests.
. Test criteria to cover complete tractor evaluation

Note: List of lectures given in Appendix A.

IV. TRACTOR DESIGN REVIEW

The objective was to review all major design features and details of the proposed new 65 HP paddy field tractor, to verify design feasibility, and make recommendations as necessary for the test phase.

A. Background

Paddy fields in general do not exceed 3,000 m^2 (80-100)m X (30-40)m and are divided by small ridges.

They present a unique problem. Since they are flooded during cultivation, tractors must be lightweight to avoid sinkage, have precise weight distribution to main trim and reduce wheel spin, be very manoeuvreable to execute the tight turns necessary in restricted areas.

Over the past 20 years China has developed, and is producing many different types of paddy field tractors. It was recognized that some degree of standardization would benefit the agricultural industry.

In 1975 a project was started to design 3 basic paddy tractors of 40, 50, 65 HP. The first phase was developed and tested with considerable success, 7-prototype tractors completing 14,000 field hours. Although not all Tractors had the intended engines, a new series of engines has now been designed and developed, on test beds to give very competitive performance and durability.

The proposed final design of the new tractor and components was the subject of an 11-day intensive design review.

Small group meetings were held with the responsible designers, major features and detail were discussed at great length and comparisons made with modern existing tractor designs.

In many areas high confidence exists since very few changes have been found necessary from the 1st phase design.

The following sections summarize the findings and discussions.

B. Engine

A 4-cylinder engine assembly is the only component seen of the new paddy field tractor series.

Its actual performance figures quoted and with a specific fuel consumption of 170g/HP/HR makes this a very competitive engine and reflects the Institute's strength in engine research.

By modern standards the engine looks big and heavy. The gear pumps for the tractor hydraulics and steering give the engine extra width, and the heavy cast oil sump appears stronger than necessary.

Weight reductions were suggested, and rocker cover and side plates are in the process of being changed to pressings.

150 hours between oil changes for a naturally aspirated engine is low, 300 hours is a more normal duration.

The target of 8,000 engine hours without overhaul is unrealistic with the level of maintenance seen on most working tractors in China.

C. Cooling system

Radiator and fan installation needs improvement to it up to modern tractor standards. Increased effecienc will offset need for larger fans, etc., if a transmission cooler is eventually found necessary.

Recommendations on how to improve eff ciency were advised. The procedure and criteria for conducting complete tractor cooling tests and temperature surveys had been the subject of a full lecture.

D. Clutch

Changes to the clutch disc have been made due to unsatisfactory performance. The original organic facings have been replaced by ceramic buttons.

The initial high clutch torque ratio of over 2:1 is not considered necessary. The non linear characteristics of the belleville spring design does not reduce clutch plate load with button wear. This point should be considered if difficult engagement characteristics or high pedal loads are encountered.

E. Transmission

Changes to the original transmission have been made to provide synchronmesh between the 3rd and 4th, 7th and 8th gears.

The baulk ring synchronizer design closely resembles that used in many European tractors. The capability to synchronize the inertia masses can only be approximated by calculation due to oil drag and temperature variations etc. it is best done on a rig or tractor, however, proportions look O.K..

The first prototype transmissions suffered from slight overheating during field test, exact temperature are not known, but since the transmission and hydraulic oils are now amalgamated, close temperature studies must be made early in the prototype life, It is not uncommon for tractors in this class with larger oil reservoirs to require a transmission oil cooler. The original transmission also had a marginal lubrication condition on the lower shaft gears; ways to overcome this condition by drilling oil feed holes through the center of the shaft were suggested; also the danger of this design suffering from complete oil starvation on inclines was discussed; again early oil surveys were advocated and specific incline criteria were suggested.

F. Rear axle

No significant rear axle design changes have been made since the 1st prototype in which a differential spider wear failure was experienced, due to wrong material? There is also a differential pinion failure history on the same parts used in the currently produced 50 HP. Shanghai tractor.

Both these facts suggest the lubrication and running conditions of the differential pinions on the differential spider arms is marginal.

A full scale investigation into lubrication and fits should be started on the similar design of the Shanghai Tractor. Test should be run on the basis of tests described in the full lecture on differentials, with fits and improvements of oil flows as discussed at the design review.

G. Hydraulics

Many changes have taken place on the hydraulic system since the 1st design phase. Pump transferred from rear axle to engine mounted, amalgamation of rear axle and transmission oil, seperate control for draft and position modes, all are quite acceptable alternates to overcome 1st stage problems. There remains one fundamental. The Institute design does not permit the use of remote hydraulic valves and the tractor 3-point linkage to be used simultaneously. Most modern tractor are now designed to feature this combined use, to meet the increasing demand of power assisted mounted implements.

Some further market research should be carried out to see if this requirement will be needed for the future Chinese market.

The total oil capacity of 40 litres to serve 3 remote valves, tractor hydraulics and transmission is low by European standards, a 20% oil increase should be considered. It may well prove necessary to offset transmission lubrication problems when vehicle incline tests are conducted.

H. Four Wheel Drive

The first design of 4WD had a steering angle of approximately 40°. This was due to the limited drive angle of the universal joint at the wheel. The design also suffered from water ingress into the wheel transmission. To overcome these two problems, a total new design concept using double crown wheel and pinions for each wheel transmission has been made. This new design improves the steering angle to 50° and makes water ingress less likely. This seems drastic action to take since the new design will further increase the weight and cost.

A further analysis of the claim that 50° steering is achieved with conventional drives on foreign tractors should be made. With todays high capability of special purpose oil seals, it should be possible to eliminate water ingress.

J. Cab

The cab is a first design and it is difficult to predict that it would survive a full series of OECD impact and crush loads. The capability of the cab front "A" pillar to withstand the final crush loads looked suspect.

It was recommended that a specific test be performed on the "A" pillar with the aid of strain gauges to more accurately predict the confidence. It was also recommended that an expert opinion from the NIAE is requested when members of the Institute visit England in October, 1983.

The importance of drawing control on dimensions for cab and cab supports was stressed to ensure best efficiency of mounts.

The strength of the rear window supporting struts when supporting the window fully raised over rough terrain looked doubtful. Interference with implements was also a potential problem. "Fold up" style window would overcome both these problems.

Seat location was restricted to a total of 6 cm. movement. By Western standards and some European regulations this is inadequate, but to maintain a short wheel base tractor this was considered their best compromise. It will lead to operator discomfort for the above average height Chinaman.

K. Tractor weight

In order to produce a rugged tractor with a high reliability, the design of many features has been on a comparative basis with foreign tractors. It would appear that the design factors have been given the "benefit of the doubt". Whilst it is difficult to judge from drawings alone. The total vehicle is almost certain to exceed the power/weight target.

Recommendations and methods to determine field loads were made to form the basis of future weight reducing studies based on the analysis of induced stress.

Note: See Appendix B for new paddy tractor specification

V. VISITS AND DISCUSSIONS

A. Factory Visits

The purpose of the factory visits was to get an insight into the manufacturing facilities and practice of China's tractor industry.

1. Jiangxi Tractor Factory (25-7-1983)

The factory is in Nanchang in the Jiangxi province. It produces 40 HP tractor for paddy field and general use, it has the capacity to produce 10,000 units per year, production had fallen due to low demand.

The Factory has designed and built prototypes of a much smaller 18 HP tractor. The start date and production estimate was not made known to me, it appeared that they themselves were uncertian due to the local popularity of the walking tractor.

Factory tour

Tool room, machining workshops, transmission and rear axle assembly only.

All of the machines in the toolroom and production locations with the exception of a large West German press (for wheel discs) were Chinese made. They appeared to be well maintained and producing quality parts.

The production machines were underutilized, and those operating were overstaffed. This may have been due to the low tractor volume. All production machines were single operation, and material was by hand to the next operation.

Castings generally were of rough quality with poor matching of casting moulds.

Assembly lines were basic and followed a logical sequence. Greater use of gauges and fixtures would be a major contributor to achieving quality of assemblies. Final tractor assembly was not operating, and no finished tractors were seen.

2. <u>Shanghai Tractor Gear Factory</u> (4-8-1983)

Principle output from this factory is 10,000 tractor gearboxes and steering gears per year to support the Shanhai Tractor Plant.

<u>Factory tour</u>

Workshops for producing cutters and hobs, gear machining and heat treat, large casting machining and gearbox assembly.

The equipment for checking finished hobs and cutters was of a very high modern standard and assured a good basis for quality gear manufacture.

Main large casting machining was on a Chinese designed semi-automated transfer line. This appeared to be in some need of maintenance but was producing reasonably good quality from a poor casting.

Gear box assembly was accomplished in assembly line order but again there was no mechanically moving assembly line and very few gauges or fixtures.

<u>Tour discussion</u>

Care of parts prior to heat treat was the main topic of the discussion, quality gears were being produced but were prone to bruising by not enough operator care in handling. More special purpose carriers and a control of over-loading stock trays, etc. should be introduced. A random check on a finished heat treated gear revealed a significant tooth error from bruising which had to be removed by hand.

3. <u>Shanghai Engine Factory</u> (3-8-1983)

This Factory was established in 1973 and was the most modern visited, it produces 10,000 units of 50 HP engines per year. Main usage is in the Shanghai Tractor Factory, although increasing numbers were being manufactured for use in road rollers and generating plants, etc. It proudly displays its 1980/82 gold rewards for quality, which seemed well justified.

Factory tour

Machining workshops engine assembly and final engine test.

Cylinder blocks were produced on a Chinese-made fully automated transfer line with remote control from a central control station, the initial casting quality was good, the combination giving a high yield of 1st class cylinder blocks.

Cylinder head and crankshaft machining was carried out with a high degree of technology.

Engine assembly was efficient and carried out in clean air conditions.

Engine test had the capability to run 15 engines and worked a full 24 hour shift system to maintain production rates.

Tour discussion

Very few suggestions could be offered to improve the operation at the current production rate.

The most significant problem was in testing of engines. All engines are run for a two-hour cycle. This is to overcome initial engine exhaust "slobber". It was pointed out that high output engine factories could not offer that running time on each engine; less than 30 minutes was more usual.

It was suggested that the problem be investigated to eliminate the initial slobber and thereby reduce test time. I advised my experience of a similar complaint which had been overcome very quickly by reducing the oil feed to the rocker shaft thus eliminating flooding of oil down the valve quide stems.

4. Shanghai Tractor Factory (3-8-1983)

This Factory produces a 50 HP general purpose tractor in 3 basic models. Production is approximately 10,000 units per year.

Factory tour

Machining workshops, rear axle and final tractor assembly, final tractor test and adjustments.

Production machines and operations were similar to the Jiangxi Tractor Factory but with higher production, machines were better utilized.

Assembly lines suffered the same lack of assembly fixtures and gauges. At completion of build all tractors were tested on a rolling road and verified for hydraulic lift capacity, before final adjustments and buy off.

Tour discussions

Main points of discussion were:

Poor quality of rear axle housing and short tool life due to heavy metal removal and adhering foundy sand.

Poor cooling efficiency of the radiator and fan assembly (also discussed at the Luoyang Institute as a continuing problem on their new designs).

Poor appearance of finished tractor, due to insufficient care in handling and storage of stock, causing rust on many parts, also the lack of uniform colour with no final paint operation.

5. General

At none of the factories enough attention was paid to "safety at work". Very few machines had guards to shield rotating cutters, or press tools, etc.

No protective clothing for operators was in evidence. With the exception of a few female operators wearing hats, examples were soft open sandles worn on feet, closeup operation of lathes, etc. with no eye protection from metal chips and swath.

General work conditions were poor and untidy by Western standards. Concern for quality was good and was recognized in many machining workshops by large display boards showing individual workers output and yield of O.K. components.

Much more could be done in this direction with visual aids to display quality defects caused by misuse and lack of care.

B. Hotel discussions

Three 2½ hour formal discussions were arranged in Nanchang, Hangzhou and Shanghai during the 14-day field trip to the paddy field and tractor factories in south of China.

Each audience was invited from local Universities, Research Institutes, local factory management, Agricultural and Machinery Bureaus.

Discussions were based on specific questions pre-set by the audience and made known to me the previous day.

In all 22 questions were set. They covered a diverse range of tractor subjects from specific design of components, to usage of test equipment and criteria to test complete tractors for world wide markets.

All questions were answered to the satisfaction of the audience albeit briefly due to time limitations.

Principle topics were.

1) Below 30 HP 4WD tractor transmission tests
2) Family series design
3) Regulations for tractors in Europe and USA
4) What lab and field tests should be carried out before mass production.

Item 1) The addition of 2 extra front driving wheels will increase the tractor limited traction by 20 %. Depending on tyre size and weight distribution, this extra torque and power has to be accounted for in the gear box strength and life factors. It follows that test criteria must be increased by proportional amounts to cater for the new drawbar potential.

Item 2) The family design principle of maximum standardization of parts and minimum service differences was explained . Bore and stroke details were given as the basis of an engine family of 3,4,6 cylinders which, with turbo charging and intercooling, produce 41 to 184 DIN HP. Supporting transmission and rear axle families are matched and mixed to cover the complete tractor range. Benefits of low manufacturing costs, low inventories, quality improvements, etc., were discussed.

Item 3) No precise details of USA regulations could be given. The main European regulations of speed, noise and safety were explained in detail, with legal limits quoted. Many other regulations including, lighting, smoke, visibility brakes, operator space, etc., were discussed in general terms.

Item 4) A typical test requirement prior to production was suggested as follows:

1st stage design
- 7 prototype tractors
- 150 specific track and laboratory tests.
- 1,000-2,000 field hours

2ND stage design
- 14 prototype tractors
- 250 specific track and laboratory tests.
- 10,000-15,000 total field hours

Pilot production stage
- 7 pilot tractors
- 50 specific track and laboratory tests
- 500 Field hours

VI. PADDY FIELD TRIALS

The objective of the demonstrations was to gain a better understanding of the main requirements and conditions of paddy field cultivation,also the type of implements used. This was necessary in order to pass judgement during subsequent design reviews of proposed new paddy field tractors. Although the demonstrations were only for a few hours duration, much valuable information and observation were made. During the many days and nights of train travel, a lot was learnt from my accompanying senior engineer on the local agriculture, as we passed through each province.

Approximately ten demonstrations were held away from Nanchang in the Jiangxi province. Four equal size paddy fields,approximately 80x30 metres,were used to demonstrate 50,40,30,18 HP tractors with typical paddy field implements.

50 HP Tractor

This tractor was fitted with a PTO rotovator. The work rate of this combination was high. It was difficult to judge at what depth the rotovator was working,but there was no evidence of the previous rice root or stubble. It did not disturb the paddy mud too deeply. It left the paddy flat and level (a main essential) so that immediate rice planting could take place.

This type of cultivation was without doubt the best demonstrated. With further studies for optimum blade design and speed of the rotovator, this method has high potential as a single pass operation. In order to satisfy the requirement of cultivating up to the edge of the paddy, wider rotovators could be used, or, if though PTO power restrictions, an offset rotovator design could be considered in combination with suitable linkage stabilizers.

40 HP Tractor

This tractor was operating with a 3-bottom mouldboard plough. It was having difficulty in keeping "on the move". This was due to the plough "digging in". Constant adjustments of the hydraulic lift were necessary by the operator. This left an unsuitable ploughed condition as the paddy was very uneven. The tractor eventually got burried up to the axles with complete wheel spin out and had to be recovered by a second tractor.

The tractor was being operated in draft control. When the draft control sensed lift corrections, the resultant transfer of weight to the rear axle caused sinking of the rear wheels into the paddy. Total tractor performance would be improved with a more sensitive hydraulic system governed by a flow control valve. This would allow smaller lift corrections. Hydraulic design should also feature draft control down to a pre-set depth maintained by position control. The use of a differential lock on this model would reduce wheel spin, thereby help maintain forward motion of the tractor. The use of a secondary trailed leveling implement similar to those used in preparing seed beds in Europe could be developed to avoid a second pass of the tractor before rice planting.

30 HP Tractor

This tractor was operating with a 2 row "cut out" disc, it was cultivating at a fast rate but was not working at a depth necessary to completely cover the previous rice stubble. This may have been due to lack of tractor power. The paddy condition was unsuitable for direct rice planting and would need a second pass to level.

The implement would have been better matched to a larger powered tractor where a greater depth of cultivation could be achieved to bury the rice stubble.

18 HP Tractor

This tractor was a new prototype from the local Jiangxi tractor factory. It was fitted with a small 3-bottom mouldboard plough. The work output of this well matched combination would compare well on a HP basis with the larger tractors. Although depth adjustments were made by the operator, the tractor kept going, productivity was improved over the larger tractors by the better manoeuvreability.

This tractor would also perform well in the many smaller and irregular shaped paddy fields seen in that province.

General observations

From my experience with modern tractors, four wheel drive tractors will perform well in paddy conditions. It is a well proven fact that most benefit from 4WD is derived in slippery and lose soil conditions where wheel slip is most likely to occur.

Although much research has taken place in developing the high lug paddy tyre most frequently used. Full consideration should be given to the European trend towards wider radial tyres. These tyres give better floatation and traction, their construction allows more tyre deflection which lowers ground pressures and provides good self-cleaning properties. Both these features are important in paddy conditions, Extra resultant width would have to be catered for by wider furrow widths, wider rotovators or wheel disc design.

It was interesting to speculate that the leveling off of the paddy fields after the demonstration would be done in the traditional way by some of the 2,000,000 working water buffalo in the Jiangxi province.

VII. RESULTS OBTAINED AND THEIR UTILIZATION.

The attainment of objectives on this mission is difficult to quantify. There was no practical work. After the first few days a friendly relationship developed and discussion increased. All main objectives of the mission were completed. Main transfer of technology was through the lecture series and the subsequent discussions. A great interest was shown in the subject of tractor and component testing. Traditionally tractor testing has been essentially restricted to field work. With my knowledge of tractor design and evaluation I was able to create a new awareness and belief in the extent and value of specific laboratory and vehicle testing.

From the detailed discriptions of facilities given, the procedures and criteria suggested, the Institute now has a good platform on which to develop a series of tests and procure the necessary laboratory equipment, which will totally evaluate a new tractor range.

During an intensive design review of all drawings for the proposed paddy field tractor many technical views were freely exchanged. Suggestions to improve component design detail were made and adopted, cautionary points were made for further investigation. No major design changes were made since prototype parts are in the final stage of manufacture.

The important factor of design and test control was dealt with at length, all concerned recognized the need for a more professional approach. Since the control documents and systems presented are well proven in large industries, acceptance in principle was agreed.

It is my opinion that final testing and time will confirm attainment of the project objectives.

VIII. FINDINGS

A. Project Control

In the short duration of the mission not all aspects of the responsibilites and control systems have been fully appreciated. However, it is the opinion of the expert that the project under review is very fragmented. Unless positive steps are taken at an early stage, the attainment of the objectives set for the performance and reliability of the tractor will not be met.

The present understanding of the project status is:

- Designed at Shanghai-responsibility shared by the Institute and Shanghai engineers.
- Prototype tractor build at Shanghai.
- Field tests at Shanghai.
- Performance tests at Luoyang.
- Laboratory tests-no specific plan, with the limited Shanghai facilities, Luoyang will play the major role.

As the first stage to overcome this situation, the following actions should be taken to form base documents from which control can be effected.

Conformation tests

A series of tests required to qualify the design must be compiled. The document is the responsibility of design engineers both at the Institute and Shanghai. It must be an agreed listing with test targets developed to completely qualify the tractor performance and durability.

As it is a living document, it must make provision for test results and achievements to be recorded at frequent intervals during the testing phase. It should be updated with new criteria as developed.

It will serve as the document for all future models and provide the Institute with information which is sadly lacking.

Test Plan

With the complete understanding of what it is you want to do, a test plan must be developed. Test planning should start as soon as possible in the design stage. It is the responsibility of the design engineers to develop a plan on a calendarised basis. It must include all "conformation tests", details of tractors or components to be used, the source of the material and the location of the test. The early development of the plan is an aid in determination of testing needs for material and facility, etc.

Test instruction

Since testing is the only means of confirming targets, it follows that precise test motivation is essential to conduct meaningful tests. It is the responsibility of the design engineer to indicate:

- Conditions requiring tests.
- Information to be gained.
- What methods or procedures to be used.
- Source and availability of material.

Design reviews

With fundamental documents in place, systematic reviews can take place.

The specific advantages of this type of control are:

- Establish an organized forum for discussion of problems and open issues.
- Provide all working levels with definite direction.
- Increase focus of effort on major problems.
- Minimise the possibility of failing to meet all objectives.
- Utilize the collective experience and judgement of representives from the affected activities.
- Allow more efficient coordination between activities through direct communication.

Base document formats to cover all points raised on this very important aspect of design and test management have been given to the Institute.

A complete set of "Conformation tests" and suggested test targets for some component, assemblies, and total tractor have been given in the lectures.

B. Facilities

The Institute does not have enough laboratory facilities to conduct tests necessary to qualify a new tractor model.

The usage of the existing facilities can be broadly summerised as follows:

. Facilities in every day use .
  Engine dynamometers, Machine workshop, Materials laboratory.

. Facilities not in frequent use.
  PTO dynamometer, Test track, Bump course, Hydraulics laboratory.

. Facilities in the final stages of development.
  Clutch & Transmission rig.

. Facilities in the process of being built.
  Rolling road, Soil bin.

Those sections of the facility which will be needed to test the new tractor series and are currently not in frequent use, should be urgently brought into full operational use. All necessary supporting equipment, instrumentation and personnel experience must be prepared if the Institute is to respond to the test needs in a professional way.

Some examples are:

. PTO dynamometer.
  This facility is ideally suited for initial cooling performance tests and temperature surveys; procedures to conduct tests are known to the Institute but it is essential to prepare for the "real thing" by conducting tests on existing tractor and solving all the detail problems that exist.

- Test track

  Trials and training for noise and durability track tests should be carried out to establish supporting needs and procedures also to solve the many problems that will be presented and must eventually be overcome.

- Transmission rig.

  This is a first class expensive clutch rig which has a dual design purpose to test complete tractor transmissions. Power transmission is the main purpose of the tractor. Tests on currently produced transmissions with known service histories should be tested now to prove rig function and give useful rig correlation data badly needed to qualify the new tractor transmission.

The Institute has no suitable basic system to apply simulated service loadings to components and vehicles undergoing fatigue and durability tests.

It is essential if the Institute is going to pursue agricultural research that a "Servo Hydraulic Test System" is provided and made operational as soon as possible.

The essential feature of the servo hydraulic system is that the flow of oil from the hydraulic pump to the load applying ram is controlled by an electrically operated valve so that the load and stroke of the ram is made to follow a pattern dictated by the control unit. The control unit can command the ram to follow:

- a sine wave form of pre-determined frequency, amplitude and mean level
- a pre-determined number of cycles at a chosen frequency and amplitude
- a magnetic tape previously recorded on a vehicle a component operating under service conditions

It is suggested the initial installation should consist of:

- 100 HP hydraulic power pack
- 2 x 2,000 kg rams
- 2 x 5,000 kg rams
- 4 control units with facility to command sine wave,

block programmes and magnetic tape.

SERVOTEST CONSULTANTS LTD LONDON is a suitable potential source. Commission of the new facility should include training and technical guidance. Comprehensive maintenance manuals, translated into Chinese, are essential if continued use is to be assured. Too often machines are seen inoperative for the lack of simple understanding.

When facility is fully commissioned the need may well arise for assistance from an expert skilled in the art of computer aided fatigue analysis.

The existing computer facility of 3 mini computers is totally inadequate for tractor research and development.

C. Design review

The new design of tractor has good prospects of reliability, since it is based on proven foreign designs and has already performed reasonably well in the 1st phase of field trails, 7 tractors completed a total 14,000 hours.

The traditional influence of robustness is evident, it is predicted to exceed target weight. This will not adversely affect the tractor performance in dry conditions, but will be to its disadvantage in paddy conditions. Only after the determination of field loads can work safely begin to reduce strength factors. Load determination may well prove that this tractor has potential to be a family member in a higher HP class. Turbocharging the proposed engine would produce 80 HP and put the power-weight ratio into a more competitive position.

Although judgement from drawings is difficult, the new cab style and operator environment would not seem to match that of a modern tractor.

It is general practice to style cabs, etc., from studio models and "mock ups". In the absence of these preliminaries, it may be necessary at an early prototype stage to make changes to improve operator comfort, convenience of controls, visibility, etc., particularly with the very limited seat adjustment.

D. Personnel

The Institute lacks personnel with experience of laboratory and rig performance testing for tractors. Although there is shortage of laboratory equipment, valuable experience could be gained if the existing equipment were more effectively used to establish data necessary for design improvements.

Until more facility is available, immediate experience can be gained from the many tractor testing stations and institutes throughout Europe engaged in the activity of testing and research into new tractor technology.

There is also lack of agricultural and manufacturing experience. Total understanding of tractor field use is most important for design appreciation. The benefit of manufacturing experience is reflected in a better feasible design detail to produce improved quality at reduced cost.

The "management structure" is poor. The full potential of the specialists groups is not achieved due to the lack of systematic co-ordination. Management training seems inadequate in the quest to gain advanced technology. This sector of engineering is fundamental, and more attention must be paid to it. It is suggested that some engineers be trained in this specialists field using their basic technical knowledge to the best advantage.

E. Manufacturing

In the tractor factories visited, there were many examples of bad castings, unclean and untidy work areas, lack of sufficient protection of stock, etc., which in all add up to a below average quality product. It was also observed that in certain areas, in particular, in the more modern Shanghai Engine Factory, they were using first class castings, they worked in clean air conditions for assembly and had the latest fully automated remote control transfer machines. The net result in this factory was that a high quality engine with good appearances was produced.

It can only be concluded that manufacturing technology is available in China, and with time the industry will compare with all modern standards.

In the meantime, however, many improvements can be made to production quality with a minimum investment of money.

A positive management approach must be made to create a quality awareness within the factories and the staff.

Organized quality reviews involving the actual production workers could very well solve many of the minor quality defects.

A tidy, well organized and disciplined work area is the basis for good quality.

ACKNOWLEDGEMENT

The expert would like to express his special thanks to all personnel of the Luoyang Tractor Research Institute of China for all their friendly help and co-operation given during the mission.

APPENDIX A List of lectures

1. Agricultural trends in Europe.
2. Test equipment and facilities for accelerated laboratory, track and field vehicle tests.
3. OECD performance testing, details of tests and tractor preparation.
4 New tractor programme, organization, control, timing and vehicle schedules.
5. Design of vehicle controls, test procedures and criteria.
6. Cab design, test procedures and criteria.
7. Synchronizers design, application, test procedures and criteria.
8. Power shift, Front wheel drive and Derivative tractors.
9. Engine design, performance, test procedures and criteria.
10. Transmission design test procedures and criteria.
11. Agriculture in Europe (Jiangxi Tractor Factory).
12. Paddy field trials and Factory visits.
13. Differential and differential lock design, test procedures and criteria.
14. Evaluation of vehicle cooling systems and temperature surveys.
15. Transmission test equipment design.
16. Specific vehicle test procedures and criteria.
17. Accelerated laboratory tests and field correlation.
18. Brake test procedures and criteria.

APPENDIX B Tractor Specification

Vehicle		objective
Base tractor weight:	standard	2200 kgs
	4 wheel drive	2400 kgs
Wheel base		2.08 m
Front track width		1.35 m
Rear track width		1.40 m
Clearance		470 mm
Tyres front:	standard	6.50 x 20
	4 wheel drive	8.30 x 24
	paddy wheel	6.50 x 26
Tyres rear :	standard	13.6 x 32
	paddy wheel	9.50 x 36
Max speed		28 K.P.H.
4 cyl Direct injection Engine		
HP at rated speed		68 HP at 2200 RPM
Bore/stroke		100/125 mm
Max torque at 1300 RPM		25.5 kgfm
Toque back up.		15%
Specific fuel at rated speed		170 g/HP/HR
	at max torque	165 g/HP/HR
Engine weight		420 kgs
Transmission clutch/dia.		Independent/280 mm
PTO clutch/dia.		Independent/280 mm
Gears forward/reverse		16/8
Synchronmesh		3-4 and 7-8
Creeper gears		8
Rear axle spirial bevel ratio		4.625:1
Planetary final drive ratio		5.25:1
Wet brakes dia.		302 mm
Differential lock		center spline
PTO RPM		540 and 1,000
Hydraulic pump capacity		30.8 l/min
Hydraulic pressure		160 kg/cm^2
Lift capacity		1,600 kgs
Hydraulic remote valves		3

APPENDIX C

The Luoyang Tractor Research Institute

Luoyang Tractor Research Institute was founded in 1957 on the basis of dividing the Automobile and Tractor Research Institute that was established in 1952 in the capital of Beijing.

The Luoyang Tractor Research Institute is a specialized research unit being responsible for researching basic theories of tractor, and for developing new products of agricultural tractors, for introducing new science and technologies, new processes, new material to tractor industry, and for running tractor test and evaluation, as well as components research. It carrys out diversified research works on those which are fundamental and general. The tasks are summarised as:

1. Studies of the technique and economic analysis of agricultural tractor;
2. To work out the series spectrum of agricultural tractor and develop tractors or series which are important and crucial to the agricultural economy;
3. The application of new materials, new technologies to building agricultural tractors;
4. Fundamental studies of agricultural tractor including new principles and structures, basic parts and components, hydraulic technology, strength of materials and parts, and measuring techniques and equipment;
5. Assimilation and dissemination of information, and consultant as well as service;
6. To study the test techniques of agricultural tractors and to test and appraise the products cared by Ministry of Machine Building;
7. To formulate National and Ministry Standards of agricultural tractors.

Since its founding, LTRI has developed agricultural tractors strictly according to the country's actual conditions. Varieties of agricultural tractors have been developed on the basis of deriving experience from both domestic tradition and abroad.

In the past twenty years, more than 70 major research results have been completed by LTRI or by joint efforts of LTRI and other units concerned. Some results were awarded prizes by the State or the Ministry such as power tillers 4x2 and 4x4 wheel tractors from 12-160 HP, boat tractor, "90" diesel engine series, and so on. LTRI has played an important part in developing tractor industry of China and in upgrading the level of scientific research work.

With a possession of more than 22,700 copies of books in Chinese and foreign languages, more than 60 types of foreign magazines and periodicals, more than 200 types of Chinese magazines, as well as varieties of information material, the library of LTRI is the largest centre of books and reference materials specialized in tractor domain. LTRI edits and publishes periodicals entitled "Tractors and Tractors Abroad".

LTRI has a staff of 770 of whom 222 are engineers and 131 assistant engineers. It covers an area of 13.5 ha, and the floor space is about 33.000 m^2. Under the supervision of LTRI there are 13 units, namely:

1. Whole Tractor Research Division
2. Whole Tractor Test Division
3. Transmission Research Division
4. Hydraulic Research Division
5. Undercarriage Research Division
6. Engine Research Division
7. Material and Technology Research Division
8. Information Research Division
9. Technology Development Forecast Division
10. Standard Research Division
11. Instrumentation Research Division

12. Measurement Technique Research Division
13. Experimental shop.

In the days to come, LTRI will closely according to the overall development of China's agriculture go on to explore new tractor technique of agricultural mechanization, develop agricultural tractor products as well as foster qualified research workers. LTRI is also willing to extend the international exchange and to serve the cause of agricultural mechanization of the developing countries.

APPENDIX D Representatives met

Beijing

Name	Duty or title
Wang Runjie	Member of Foreign Affairs Bureau of the Ministry of Machine Building
Lu Zhongming	Director, chief engineer of Agricultural Machinery Bureau of the Ministry of Machine Building
Zhen Gui	Deputy chief engineer of Agricultural Machinery Bureau of the Ministry of Machine Building

Luoyang Tractor Research Institute of China

Cai Jeiren	Director of LTRI
Kong Depong	Executive Vice Director, Chief engineer of LTRI, Member of Standing Committee of CSAM
Lu genyuan	Deputy Director, Deputy chief Engineer of LTRI
Fu Yunfang	Deputy Director of LTRI
Jin Yaokui	Former Director of OTRI, Consultant of LTRI
Gu Luping	Head of Chief Engineer Office of LTRI, Member of SAE and ASAE
Fun Wuchu	Senior engineer, Head of Whole Tractor Research Division
Shi Jiong	Senior Engineer
Cai Dingzhong	Engineer
Wu Zhili*	Engineer
Wang Daxong	Engineer
Lin Minwen*	Engineer
Xu weien	Engineer
Su Fugong	Interpreter
Nim Shizong	Interpreter

Jiangxi Tractor Factory

Xie Chunhuang	Chief designer, Senior Engineer
Xiang Xiiang	Senior Engineer
Zhu Deyan	Senior Engineer
Den Songshan	Head of the Jiangxi Agricultural Machinery Management Department
Chen Kun	Jiangxi Province Agricultural Machinery Company
Wu Yuanbao	Engineer, Jiangxi Province Agricultural Machinery Institute

Hangzhou

Lu Shangwer	Engineer, Machinery Research Institute of Zhejiang Province
Yang Zhong	Engineer, Forestry Research Institute of Zhejiang Province
Xi Wenbin	Associate Professor, Zhejiang Agricultural University
Ye Xinhu	Engineer, Ningpo Tractor Factory

Shanghai Tractor Factory

Wu Shounan	Vice Chief-engineer
Wang Zigao	Chief of the Factory Production Office

Shanghai Internal Combustion Engine Factory

Yuan Ruiji	Manager
Zhao Enfa	Vice Chief-engineer

Shanghai Tractor Gear Factory

Zhu Xinggao	Vice Manager
Lu Shunlong	Engineer

* female