



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

RESTRICTED

DP/ID/SER.A/960
1 February 1988
ENGLISH

16842

UPGRADING OF THE ECONOMY AND RELIABILITY OF THE
LOCOMOTIVE DIESEL ENGINE, SIFANG

DG/CPR/85/018/11-01

THE PEOPLE'S REPUBLIC OF CHINA

Technical report: Design and planning review for development
of locomotive diesel engine*

Prepared for the Government of the People's Republic of China
by the United Nations Industrial Development Organization,
acting as executing Agency for the United Nations Development Programme

Based on the work of Mr M. Behrens
UNIDO expert

Backstopping officer: H. Seidel, Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

* This document has been reproduced without formal editing.

V.88-20973

Explanatory notes

Value of local currencies during the period of the mission

The People's Republic of China:
100 Yuan = 26.954 US\$
100 US\$ = 371.00 Yuan

Republik Österreich
100 Schilling = 8.36 US\$
100 US\$ = 1196.29 Schilling

Abbreviations

AVL -AVL-Gesellschaft für Verbrennungskraftmaschinen
und Meßtechnik mbH Prof.Dr.Dr.h.c.Hans List,
Graz, Austria

CICETE -The China International Centre for Economic and
Technical Exchanges

CTA -Chief Technical Adviser

Sifang -Sifang Locomotive and Rolling Stock Works,
16 Hangzhou Road, Qingdao, The People's Republic
of China

ORE -Office de Recherches et D'Essais

UIC - L'Union Internationale des Chemins de Fer
Oudenoord 60, NL 3513 EV Utrecht
(Telex 70 4 69 ore ni)

Abstract

The project of the Government of The People's Republic of China 'Upgrading Economy and Reliability of Locomotive Diesel Engine' number CPR/85/018/A/01/99 agreed with UNDP March 28, 1986, started on the foundation of a contract between The China International Centre for Economic and Technical Exchanges (CICETE) and AVL-Gesellschaft für Verbrennungskraftmaschinen und Meßtechnik, Graz, Austria, in November, 1986. Besides, this project aims at a transfer of technology. The contract expires after four years, but the objective is planned to be finished against end of 1989.

The first step of the project, this is the preliminary and final layout of a new advanced diesel engine was finished in November, 1987. CICETE/Sifang worked together with AVL consequently, properly and intensively for the implementation of the objectives. The co-operation with AVL and the progress on the project meets the demands.

Nevertheless, it is necessary to prolong the working plan for the whole project from 37 months up to 40 months because a completely new development of the engine was indispensable against the project objectives planned; that means a greater expenditure of development and of engine parts.

The last detail drawings will be finished and checked in April, 1988. For some important engine parts are detail drawings available to already start production for prototype engine. It is foreseen to start the engine test at AVL against the end of 1988.

Furthermore, conclusions and recommendations are included in the report. Some pieces of advice are given thereafter.

Table of contents	page

Coverpage	1
Explanatory notes	2
Abstract	3
Table of contents	4
Introduction	5
Recommendations	8
I. COURSE OF DIESEL ENGINE DEVELOPMENT	11
A. Co-operation between CICETE and AVL	11
B. Cours of co-operation	12
II. ACTIVITIES OF CTA	14
A. Activities in Qingdao	14
B. Activities in Graz	15
III. PROSPECTIVE COURSE	17
Conclusions	18
Annexes	
Senior counterpart staff at Sifang Works, Qingdao	19
Senior counterpart staff at the meeting between Sifang and AVL 9.-18.12.1987 in Graz, Austria	20
Visit to Sifang Locomotive and Rolling Stock Works in Qingdao	21

Introduction

Sifang Locomotive and Rolling Stock Works located in Qingdao has manufactured over 1,000 IDI 12 V 180 diesel engines. In order to upgrade the performance (from 1350 HP to 1800 HP at the same speed 1500 RPM), the economy and the reliability of the diesel engine a technical assistance project was agreed upon between the Government of The People's Republic of China and the United Nations Development Programme (UNDP) in March 1986. The improvement is urgently needed for the present design of diesel engine due to the high fuel consumption, short time between overhauls and in order to meet the requirements of railway power classification.

The United Nations Development Programme provides an input of 2,009,800 US\$ and the Government of The People's Republic of China an input of 2,510,000 RMB Yuan (in kind) for the project. The development objective is determined by an improved fleet of locomotive diesel engines with extended live time, reduced consumption of fuel and longer time between overhauls. A further objective of the project is to strengthen the capability of the Sifang Locomotive and Rolling Stock Works in the field of design, development and testing of improved modified locomotive diesel engines, which will meet international standards and requirements of railway engine power classifications. Therefore, the project will assist in the transfer of technology which will enable the Sifang Factory to carry out these tasks on its own through the acquisition, adaptation and development of the required technology.

The project activities are mainly carried out by co-operation of the Sifang Factory with a sub-contractor in four distinct phases in operation:

Initial Phase: Preparation of detailed terms of reference for a sub-contractor, of tender documents and inviting bids from potential sub-contractors. Contract with the chosen sub-contractor.

Phase I: Prepare preliminary layouts of a modified engine for decision. Preparation of final layouts and detailed drawings.

Phase II: Build prototype of the improved engine according to modified drawings. Make modifications to correct the prototype engine if needed.

Phase III: Carry out development work at a test stand on the prototype of the improved engine and record all engine performance data. The engine shall reach the performance characteristics cited in the contract.

Phase IV: An advanced testing laboratory for the diesel locomotive engine will be established at Sifang Factory with required equipment and instruments. Endurance and cycling tests according UIC-100 hr and ORE-1000 hr cycle and endurance tests on Sifang test stand. Undertake final revision of all engine parts of the prototype as necessary and undertake modifications of a limited number of existing diesel locomotive engines as a part of demonstration and experimental process.

Present situation: A contract between The China International Centre for Economic and Technical Exchanges and the sub-contractor AVL - Gesellschaft für Verbrennungskraftmaschinen und Meßtechnik, Graz, Austria was signed on July 23, 1986. The contract is valid for four years from the date of effectiveness.

The phase I started in November, 1986, and should be finished within twelve months. During a first meeting between Sifang and AVL held in April, 1987, the layout of the advanced engine was confirmed. The final layout was verified in a second meeting in December, 1987. The third meeting is planned for May, 1988, to confirm all detail drawings. It is planned to fulfil all obligations within thirtyseven months.

A Chief Technical Adviser (CTA) was recruited by UNIDO in November, 1987 and this is his first report.

The report is intended to give a survey on the actual situation of project, problems occurred and proposals for further activities and decisions to be reached on. Therefore, the report should be additionally distributed to Sifang Works and sup-contractor AVL.

Recommendations

1. Compared with the time schedule of the Contract between CICETE and AVL a delay of about one month has already occurred, and a further delay of additional two months against the time schedule is expected for the phase of production of the prototype engine. In this way the whole progress of the project will be prolonged from 37 months to 40 months.

Planning the project by CICETE/Sifang the idea existed that only changes of the previous diesel engine would meet the set objectives. The prolonged period is necessary for a large scale of changes of the previous diesel engine which was not foreseen at the beginning (see also item 2), because a completely new development of the engine is necessary and the period for producing new parts will be longer. So the required change in the time schedule of the Contract should be accepted and the production of new engine parts at Sifang Factory should be started before the planned date as soon as possible in order to minimize the risk of further delay.

2. First inline injection pumps were foreseen as on the previous engine by Sifang to minimize the changes on the engine for minor costs and this condition was fixed explicitly in the Contract. The conceptual layout of the new engine showed that minor changes of the original engine would not meet the development objectives, because a considerable increase of peak firing pressure from 100 bar up to 135 bar only ensures the improvement of the engine's fuel consumption and reliability. AVL recommended single pumps at the beginning, but worked then according to the Contract.

After three months Sifang discussed with AVL the diesel engine concept with two inline pumps which was considered to be not

•

as advanced as the engine with single pumps which was now identified as the preferred solution. Therefore the injection system was changed into single pumps on request of Sifang and a new conceptual layout of the engine was necessary. Although it was technically acceptable, AVL had asked for additional Schilling 500,000 due to the change of the engine concept. The extent of the necessary layout changes and further work is considerable. Therefore, the CTA supports substantively the use of single pumps and is of the opinion that the additional amount of 500,000 Schilling for the supplementary work would be justified.

3. During the negotiation of the Contract AVL did not agree with Sifang's wish for a general overhaul period of 36,000 hours and accepted 26,000 hours for the general overhaul period and 12,000 hours for minor overhaul period. In order to avoid the second minor overhaul at 24,000 hours, e.g. 2,000 hours before the general overhaul, AVL should aim at prolonging the minor overhaul period to 13,000 hours.

4. It is recommended that the quality of some critical parts of the engine should be separately checked as soon as possible and before setting up the engine. For example:

- Engine block on deformation and stress in critical areas
- Deformation of the cylinder head bottom under working condition
- Pressure distribution alongside the sealing of cylinder head
- One segment of crankshaft with regard to its fatigue limit
- Flow resistance of the individual passages forming the cooling system

The agreement on the date of supplying the necessary parts to AVL and the number and type should be made as soon as possible.

5. It is recommended to get more exact information on actual conditions of UIC acceptance test and ORE requirements, and if possible, to find out the suitable know-how for the tests.

6. For the acceptance tests (100 HR and 1000 HR) at the Sifang Factory, it is foreseen that the construction of a new test stand will be combined with a advanced automatic measuring/recording system. It is recommended to pre-test the test stand by using another diesel engine in order to get some experience in the UIC test procedures.

7. Sifang Factory is recommended to create the possibilities to simulate the changes of ambient conditions for the test of diesel engines.

8. The next meeting between Sifang and AVL will be in May, 1988, after having reviewed of the detail drawings by AVL. It is recommended that the CTA takes part.

9. It is recommended to review the production of parts for the prototype engine by the CTA at Sifang in autumn 1988. For fixing the exact date of the visit Sifang is requested to hand over a time schedule of the parts production till the next meeting in May, 1988.

10. Sifang thinks that the content of the AVL design report should be supplemented. AVL is of the opinion that the description of engine components are contained in separate reports such as for thermodynamics, port development, strength calculation and design. The CTA recommends AVL to condens all descriptions into one report. This is possible by annexes for example.

I. COURSE OF DIESEL ENGINE DEVELOPMENT

A. Co-operation between CICETE and AVL

The complete project is planned in steps performed by AVL, CICETE or in teamwork.

The first step includes the engine design study in view of the objectives of the project, preliminary layouts and sketches and support calculations in strength and thermodynamics performed by AVL. For final layout drawings CICETE engineers are associated with AVL performing design work under guidance of AVL.

The second step includes the detail drawings and parts list by CICETE and the review of detail drawings by AVL. Step three plans the procurement of prototype engines, test parts and spare parts by CICETE. AVL gives assistance in procurement of engine parts and components outside China. Step four involves measurements, set up and development work of one prototype engine at AVL test stand, structure investigations of critical engine areas by stress and deformation analysis and acceptance test. CICETE engineers are associated with AVL within this period also performing design work.

Step five includes the endurance and cycling tests according to UIC-regulations and DRE-specifications in view of the objectives and specific requirements of the project. These tests will be performed at the Sifang Factory. AVL will do consulting work.

B. Course of co-operation

The Contract between CICETE and AVL contains the general plan and time schedule (see III.).

The engine design study and conceptual layout carried out by AVL showed that minor changes of the original engine would not perform the development objectives. A completely new layout was necessary, because the improvement of the engine's fuel consumption and reliability can only be guaranteed by a considerable increase of peak firing pressure from 100 bar up to 135 bar and more. The CTA emphasizes this necessity.

It was essential to change the current main bearings of roller type into slide bearing system at increased cylinder centre distance. This led to a new design modification on crankcase, powertrain, liner, cylinder head, valve train and others.

The first training group from Sifang started work in February, 1987, and discussed with AVL the diesel engine concept with two inline injection pumps (made according to the contract) which was considered as not so advanced as the diesel engine with single pumps which was now identified as the preferred solution. The CTA quite agrees with them since single pumps offer more possibilities for further developments and low fuel consumption. The injection system was changed into single pumps on request of Sifang and a new conceptual layout of the engine was necessary. The extent of the necessary layout changes is considerable. Therefore AVL asked for additional Schilling 500,000 due to the change of engine concept and further performances in connection with the development of the injection system.

The first meeting between CICETE/Sifang and AVL was held at Graz, Austria, from April 6 to April 14, 1987. The results of conceptual design studies and supporting calculations in strength and thermodynamics were discussed and handed over to the Sifang delegataion. Furthermore, the list of parts to be used for the prototype engine was arranged.

During this meeting the next phase of AVL-work was agreed upon: AVL perform the final layout design and detail calculations in teamwork with Sifang design engineers for optimum transfer of know-how and deep understanding of AVL preliminary layout drawings and supporting calculation work. AVL recommended a production expert should be associated with AVL for discussing production problems, casting and machining questions. The expert performed this task.

In the meantime the final layout has been finished, against the plan with about one month delay. The second meeting was held at AVL, Graz, Austria, from December 9 till 18, 1987. It was aimed at discussing the results of the final layout work and supporting calculations:

- Design report and final layout
- Thermodynamic report
- Valve port development report
- Calculation of crankshaft, bearing, gear train, pumps, valve train, general calculations

The following items were agreed upon:

- Parts procurement for prototype parts by AVL
- Engine transportation and set up on test bench
- Production of prototype parts at Sifang
- Parts, necessary for deformation analysis at AVL
- Further procedure on project (review of detail drawings)
- Spare parts needed

It is expected that the detail drawings will be finished step by step by Sifang reviewed by AVL till end of April 1988. Sifang is in a position to start production of important engine parts already. The needed drawings are available.

II. ACTIVITIES OF CTA

A. At Sifang Factory in Qingdao

The duration of stay in Qingdao was from November 7 till 20, 1987. The main duties were agreed on proposals of Sifang Factory and CTA fixed in a schedule.

After a factory tour (s. annex) and review of project document and contract work, discussions were held on the project work, the viewpoints of preliminary layout and final layout of diesel engine, especially the relationship between the M.E.P./P.F.P. in the cylinder and reliability of diesel engine which is very important for a diesel engine. The discussion turned out a lot of technical questions, some of which were answered by the CTA with recommendations and some of which are to be cleared up between CTA and AVL. The following items were discussed:

- Requirements on the project and comment on progress of project
- Final layout and performance of diesel engine
- Stationary part, moving part and valve timing system of diesel engine
- Machining process
- Testing equipment and acceptance test work
- Recommendation for work of next step

The CTA was asked for two lessons on diesel engines which were presented:

- Development of world high powered diesel engine
- Combustion system and valve timing system of high powered diesel engine

During the lectures the CTA discussed and explained some technical problems, especially the problems concerning the development of advanced locomotive diesel engines.

Chinese partners expressed their satisfaction about the teamwork with the CTA.

The CTA expresses his thanks to the Chinese partners for their friendly and helpful cooperation including excellent cultural services besides the duties.

B. At AVL in Graz

To get an idea of the whole progress of the project the sub-contractor AVL was looked up in Graz on November 26, 1987.

The questions asked by Sifang and some recommendations given in this report were discussed. The CTA is of the opinion there are no doubts that the work on the tasks is performed in a straightforward and technically correct way by AVL in teamwork with Sifang engineers associated at AVL.

Furthermore, the additional expenditure of work was discussed brought about by the change of the engine layout from inline injection pumps to single pumps at AVL after three months of working hours. The extent is considerable because the diesel engine was designed with a camshaft arranged in the V-angle of the cylinder banks at the beginning. After this two camshafts

were necessarily arranged for the single pumps at the outside of the V-angle. That means a fundamental new layout. Besides this the expenditure for the engine design is greater than for inline pumps.

The further steps of work were discussed, and it was considered necessary that the CTA should take part in the following meeting between Sifang and AVL in December 1987. UNIDO confirmed this during the debriefing in Vienna.

The meeting took place in Graz from December 9 till December 18, 1987, and the CTA took part from the 11th till the 18th.

According to the aim fixed the AVL design report and the supporting calculations were especially discussed. The explanations were extensive and there was no reason for any criticism. On the other hand Sifang considered the written report as too concise. The CTA is of the opinion that it would be more favourable to supplement the report by the host of reports presented singularly to Sifang. This would be better for good survey.

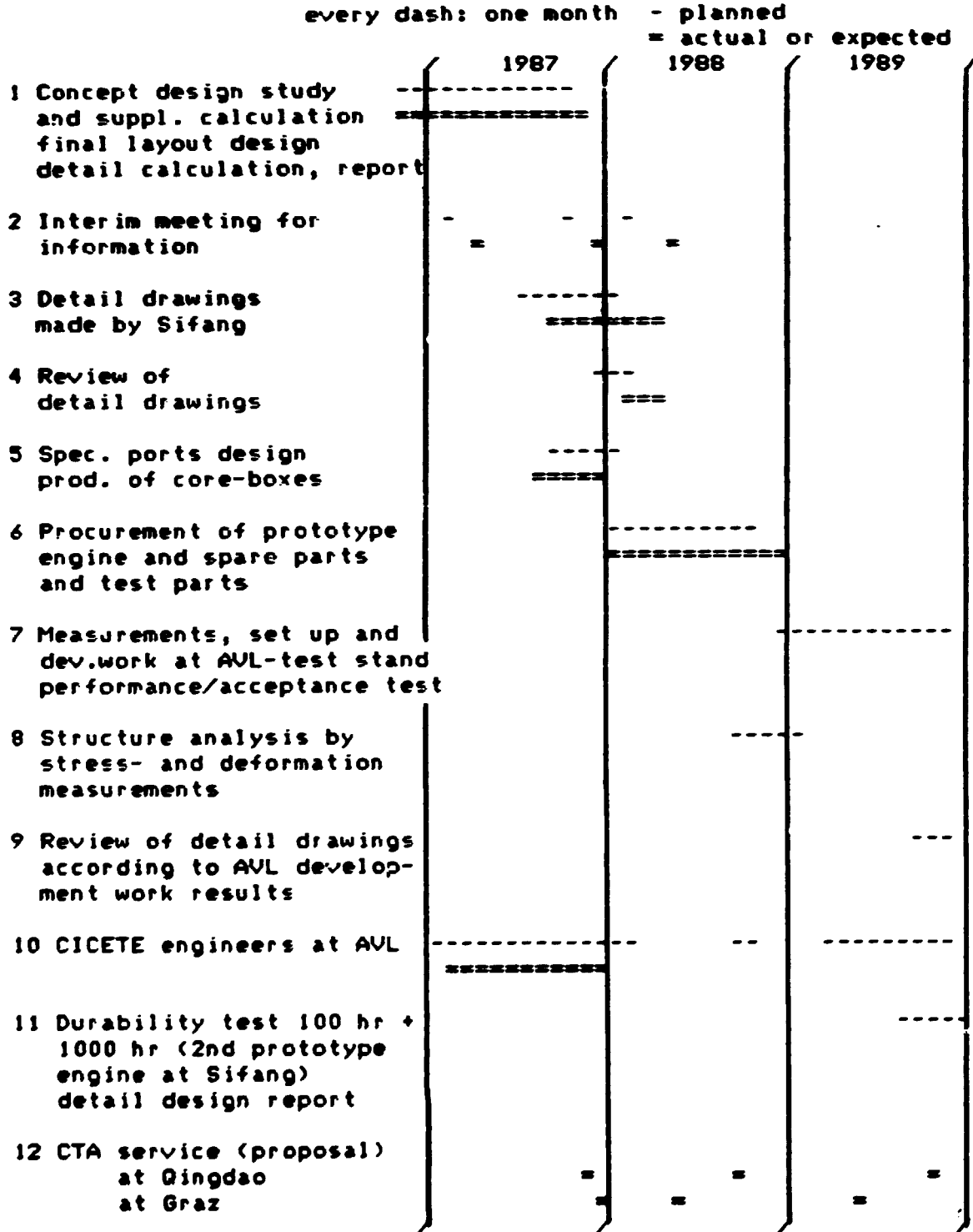
The next steps of work were agreed upon. Sifang will finish the detail drawings step by step and will in this way deliver the drawings to AVL for reviewing. With that the design phase will be finished by April, 1988, and the success shall be confirmed in a third meeting in May.

Furthermore, in the meantime Sifang ought to start the production of parts for the prototype engine. It is important that the parts are available for deformation analysis at AVL as soon as possible to minimize the danger of delay.

The CTA thanks Sifang and AVL for well supporting his task and AVL for the friendly care.

III: PROSPECTIVE COURSE

Based on the agreement between Sifang and AVL and regarding to the engine development started in November, 1986, the following time schedule is given:



Conclusions

1. CICETE/Sifang has worked consequently and intensively on the fulfilment of the objectives. There is no reason for any criticism on what CICETE/Sifang has done.

2. The project work has been done perfectly. In the opinion of the CTA neither changes of the objectives nor changes in the methods applied towards the objectives are necessary.

3. The Co-operation between CICETE/Sifang and AVL has been carried out smoothly and has met the demands of technology transfer specified in the Project Document.

4. Now, it is necessary to make immediately all efforts for the production and the procurement of engine parts which are needed for the structure analysis by stress and deformation measurements and for setting up the prototype diesel engine.

Prof. Dr. sc. techn. Behrens

ANNEXES

=====

Senior counterpart staff at Sifang Works, Qingdao

Mr. Qi Weng	Director, Engineer
Mr. Huan Anjung	National Project Director, Chief Engineer
Mr. Ji Pei	Vice-chief Engineer
Mr. Liu Zheng-qi	Engineer (Deputy Chief Engineer)
Mr. Gong Xin-lin	Engineer (Deputy Chief in Design Section)
Mr. Jiang De-zhan	Engineer (Interpreter)
Mr. Liu Hong Dong	Engineer (Interpreter)
Mr. Xie Yi-ping	Engineer (for tests)
Mrs. Dong Zhi	Engineer (for design)
Mrs. Gao Yan-hua	Engineer (for design)
Mr. Wang Chui-tai	Engineer (for production)

Senior counterpart staff at the meeting between Sifang and AVL
9.12.-22.12.1987 in Graz, Austria

Sifang-Delegation

Mr. Long Pingsheng Vice-Director, Engineer
Mr. Liu Zheng-qi Deputy Chief Engineer
Mr. Shi Jia-lin Engineer
Ms. Dong Zhi Engineer
Mr. Zhang Bai-ru Engineer
Mr. Wang De Yong Engineer
Mr. Qui Yan-Tai Engineer
Mr. Jin Guang Engineer
Mr. Zheng Liang qing Engineer
Mr. Xu hui Engineer

AVL-Participants

Mr. K. Wojik Executive Vice President
Mr. M. Sucher Deputy Vice President
Dr. J. Affenzeller Applied Mechanics & Stress Analysis Dpmt.
Mr. G. Athenstaedt Development Dpmt.
Mr. R. Glanz Fluid dynamics
Mr. Herzog Calculation
Mr. W. Kling Design Dpmt.
Mr. G. Maier Design Dpmt.
Mr. U. Mayerhofer Thermodynamics
Mr. B. Obermayer Design Dpmt.
Mr. B. Pfeifer Staff Engineer
Mr. H. Wasserbäck Design Dpmt.

Factory tour: Sifang Locomotive and Rolling Stock Works

Mr. Ji Pei gave an introduction into the development and the products of the Sifang Factory.

It was founded in 1900 and is one of the 45 factories involved in the Ministry of Railways. Sifang constructed 10 types of steam locomotives and 70 types of wagons during the time. The capacity in repairing is about 500 wagons/year and 70 locomotives/year.

More than 11,000 employees including 500 engineers are working in 29 shops and 28 design offices.

Steam locomotives were produced until 1958 and then started the production of diesel locomotives. Two types of locomotives are built based on an IDI 12V diesel engine with a rated performance of 1350 HP at 1500 RPM and 1500 HP one-hour rating. The DHF3 locomotive contains two diesel engines and is mainly used in the north east of China. The DHF21 locomotive works with one engine and is mainly used for short distances.

Difficulties by cavitation at the cylinder liners of the diesel engine were overcome supported by UNIDO and AVL as sub-contractor in 1985. Nevertheless the high fuel consumption of 170 g/HP hr, the too low performance and too short time between the engine overhauls demand an improvement.

The factory tour showed everywhere the considerable efforts in improvement of production plants. But there is no doubt that similar efforts are necessary to upgrade the foundry, the forge and the machining shops. Remarkable is the new plant for hardening processes of crankshafts and similar workpieces. The erection of an R. & D. test stand is provided for.