OCCASION

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

DISCLAIMER

FAIR USE POLICY

CONTACT

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

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

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

19724

Research & Test Department

UNIDO PROJECT DP/CPR/85/019
IMPROVEMENT ON LOCOMOTIVE TEST STAND
DALIAN, PEOPLE'S REPUBLIC OF CHINA

TTC Transportation Test Center

ASSOCIATION OF AMERICAN RAILROADS

UNIDO PROJECT DP/CPR/85/019
IMPROVEMENT ON LOCOMOTIVE TEST STAND
DALIAN, PEOPLE'S REPUBLIC OF CHINA

by

A. J. Peters and
M. A. Dembosky

Association of American Railroads
Transportation Test Center
Pueblo, Colorado 81001

May 1992

DISCLAIMER

This report is disseminated by the AAR for informational purposes only and is given to, and accepted by, the recipient at its sole risk. The AAR makes no representations or warranties, either expressed or implied, with respect to the report or its contents. The AAR assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential, or any other kind of damage resulting from the use or application of this report or its contents. Any attempt to apply the information contained in this paper is done at the recipient's own risk.

1. REPORT NO.	2. REPORT DATE	3. PERIOD COVERED
P-92-106	May 1992	Jan 1988 - Sep 1990

4. TITLE AND SUBTITLE
UNIDO Project DP/CPR/85/019 - Improvement on Locomotive Test Stand, Dalian, People's Republic of China

5. AUTHOR (S)
A. J. Peters & M. A. Dembosky

6. PERFORMING ORGANIZATION NAME AND ADDRESS	7. TYPE OF REPORT / 8. CONTRACT/GRANT NO.
Association of American Railroads Transportation Test Center P.O. Box 11130, Pueblo, Colorado 81001	7. TYPE OF REPORT: Final 8. CONTRACT/GRANT NO.: 87/135

9. SPONSORING AGENCY NAME AND ADDRESS	10. NO. OF PAGES / 11. NO. OF REFERENCES
United Nations Industrial Development Organization Vienna International Center, P.O. Box 300, A-1400 Vienna, Austria	10. NO. OF PAGES: 41 11. NO. OF REFERENCES: 19

12. SUPPLEMENTARY NOTES

13. ABSTRACT

The Association of American Railroads (AAR) was contracted by the United Nations Industrial Development Organization (UNIDO) to act as technical advisor for the upgrade of the locomotive test stand at the Diesel Locomotive Research Institute (DLRI), Dalian, Peoples' Republic of China. The objective of the project was to increase the measurement accuracy and productivity of the test stand so that thermodynamic and performance testing of locomotives could be more effectively carried out.

The method of approach adopted for this project required that the technical advisors provided the necessary technical training and on-site support so that the DLRI test stand engineers could design and implement the upgrade, with the necessary equipment provided by UNIDO. The technical training was provided through a fellowship program, conducted by the AAR at the Transportation Test Center (TTC) in Pueblo, Colorado. In all, eighteen of the test stand engineers spent up to five months at the TTC gaining experience in instrumentation and computer control techniques and testing methods. Technical support provided by the AAR for the project consisted of four site missions by the AAR advisors during critical phases of the project. The project was successfull completed on time and within budget.

14. SUBJECT TERMS	15. AVAILABILITY STATEMENT
Locomotive Testing, Instrumentation, Computer Control, Data Collection, Data Analysis, Measurement Accuracy, Productivity, Dynamometer, Engine Performance, Thermodynamics.	This Document Is Not For General Distribution

This page intentionally left blank

EXECUTIVE SUMMARY

The Dalian Diesel Locomotive Research Institute (DLRI) is one of the primary locomotive research establishments in the People's Republic of China (PRC). It was opened as a locomotive test facility in 1935 and has operated as a separate research institute since the early 1960's.

In 1979 the Dalian DLRI commissioned a diesel locomotive test stand (dynamometer), which was designed and built by the institute staff. This test stand is one of only three of its type in the world. Of the other two, one is located at the Munich Test Center in the Federal Republic of Germany and the other at the AAR's Transportation Test Center (TTC) in the United States of America. Between 1979 and 1986, the Dalian DLRI test stand was used to measure the thermal performance and tractive effort of five locomotives, including the Dong Feng 4 locomotive, which was manufactured at the adjacent locomotive factory. While the tests were generally successful, in that they provided data which enabled the manufacturers to improve the basic design of the locomotives, the conduct of the test was time consuming and the resultant data less accurate than desired.

Until 1985, the Dalian DLRI was totally funded by the Ministry of Railways. However, since 1985 the DLRI has been required to earn an increasing amount of its operating costs from contracts. Since 1990, it has received no direct financial support from the Ministry or any other government department, and now relies entirely on the income derived from contracts. In order to meet that challenge, it was necessary to upgrade the efficiency and accuracy of the test stand. The United Nations Industrial Development Organization (UNIDO) agreed to fund the upgrade of the facility with matching funds being provided by the government of the Peoples' Republic of China (PRC).

The Association of American Railroads (AAR) were awarded a contract by UNIDO to provide the necessary technical support for the upgrade program, as the result of a bid submittal by the AAR in response to a Request for Proposal. The terms of the support contract were clearly defined by the Request for Proposal and its attachments. The main objectives of the project are summarized below:

- To improve the general measurement accuracy to better than 1% and to improve the accuracy of critical performance measurements to better than 0.5%.

- To reduce the time required to perform a complete engine thermodynamic evaluation and tractive performance test from four months to six weeks.

After discussions between a joint delegation from UNIDO and the Dalian DLRI and the AAR, a method of approach was adopted in which the AAR technical advisors would provide the necessary guidance for the DLRI locomotive test stand engineers to design and implement the upgrade themselves. The key to this approach was a fellowship program, which was an integral part of the project plan, during which eighteen of the test stand engineers spent a period of up to five months at the AAR's Transportation Test Center in Pueblo, Colorado. There, the test stand engineers were provided with the necessary background training in instrumentation system calibration and applications, computer control and data collection software development, and testing methods. The basic engineering training, outlined above, was augmented by four site missions by the AAR technical advisors to the DLRI. These site missions were coordinated through UNIDO and with the Chief Technical Advisor and the National Program Director. The AAR missions were scheduled so that they did not coincide with those conducted by the Chief Technical Advisor. This achieved the maximum benefit from the technical advisory resources.

Each of the four site missions carried out by the AAR technical advisors were designed to accomplish specific objectives as defined below, with the mission dates shown in parentheses.

- Facility Assessment (January 1988).
- Final Design Review (May 1989).
- Control Software Implementation Review (May 1990).
- Computer Control Software Review and System Checkout (August 1990).

The facility assessment, which preceded the fellowship program, was designed to complete the definition and outline design of the upgrade, and to develop the project implementation plan. This included an evaluation of the hardware requirements and a definition of the training requirements for the fellowship program. This mission was one of the major factors in the subsequent success of the method of approach adopted for the project. The remaining missions were designed to coincide with critical activities in the project implementation or to address specific problems.

The project generally followed the schedule laid down in the implementation plan. For example, the fellowship program was completed by the end of 1988 and the final design and equipment procurement was completed by May 1989. The tasks specified under the current contract, defined as Phase 1 of the project were essentially complete by September 1990. Only one major problem was encountered during the implementation of the upgrade. The original plan called for the additional tasks of data collection and test stand roller speed control to be placed on the HP 1000/HP 2250 computer/measurement and control system. During the course of the upgrade it was discovered that the additional circuit boards required to complete this task were no longer in production. Furthermore, maintenance support for this equipment was being phased out. An alternative system, based on the HP 360/HP 3852 hardware was selected by the DLRI test stand engineers and submitted to UNIDO for procurement. This caused some delay in the hardware installation and software development, but by developing software on other equipment, the computer engineers were able to make up most of the lost time. A preliminary evaluation of the upgraded measurement and control system has shown that the objectives for improved accuracy and productivity, laid down in the statement of work, have been met.

In the opinion of the AAR technical advisors, the successful completion of this project resulted from a combination of a sound implementation plan and good technical and administrative leadership from UNIDO, the Chief Technical Advisor, the Ministry of Railways and the National Program Director. However, the enthusiasm and willingness of the test stand engineers to implement the experience gained during the fellowship program, provided a solid technical base on which the upgrade could be successfully implemented. The fact that this approach did succeed holds much promise for the future.

Two sets of conclusions are offered regarding the status of the DLRI test stand upgrade project. First, directly addressing the conduct and status of Phase 1 of the project, the AAR advisors conclude that:

- The first phase of the Dalian DLRI upgrade project was completed on schedule and within budget.
- The measurement accuracy targets (better than 1% for general measurements and better than 0.5% for critical measurements), defined in the project objectives, have been met.

- The testing time for the complete thermodynamic and performance of a diesel electric locomotive has been reduced from three to four months to four to six weeks.

- The test team required to conduct a locomotive test has been reduced by 25% (from twenty to fifteen).

- The successful completion of this project resulted from the implementation of a well developed plan, with clearly defined objectives, carried out by a team of enthusiastic and dedicated engineers, coordinated by good project leadership.

With regards to the prospects for future enhancements to the DLRI test stand, it is the opinion of the AAR technical advisors that:

- Opportunities exist for expanding the role of the DLRI test stand in support of the Ministry of Railways locomotive research programs. In addition, the computer and instrumentation expertise, developed as a result of this project can benefit other research programs sponsored by the Ministry of Railways and in support of the local engineering enterprises.

In order to consolidate the accomplishments of phase 1 and to provide expansion capabilities for the future, the AAR technical advisors recommend that consideration be given to the following actions

- The project documentation, including the software manuals, test stand maintenance procedures, and instrumentation installation and calibration manuals should be completed to avoid the loss of vital information.

- When the opportunity arises, a complete audit of measurement and data processing accuracy should be carried out, using the set up procedures and test data from a full diesel electric locomotive test.

- The additional upgrades proposed as Phase 2 of the program, including the installation of a suspension characterization and modal analysis electro-hydraulic shaker system, should be considered to enhance the capabilities of the Dalian DLRI to support the testing of locomotives.

- The role of the Dalian DLRI test engineering expertise should be expanded to further support the Ministry of Railways research program and the testing needs of the local engineering enterprises.

- When possible, international technology transfer projects should be designed to build upon a base of existing technical expertise. When necessary, the required technical training should be provided before hardware is committed to the project.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The AAR technical advisors wish to acknowledge the role of the other participants in this project in ensuring a successful completion. First, the responsiveness of Dr. Hans Seidel and his colleagues at UNIDO to the recommendations and requests made by the implementation team, together with the strong project direction provided by the UNIDO staff, were major contributions to the success of this project. The excellent technical leadership provided by Dr William J. Harris Jr, as the UNIDO Chief Technical Advisor, ensured that the technical objectives remained firmly in focus. The interest and support provided by the Ministry of railways, who co-sponsored the project and approved the plan, was instrumental in the smooth implementation of the project. However, it was the Dalian DLRI test stand engineers, with the expert leadership of Chen Chougui and Li Dunkang as successive National Program Directors, who guaranteed the success of the project. Their willingness to accept the technical training provided during the fellowship program at the TTC and then effectively applying it to the DLRI test stand upgrade project was exemplary.

Finally, the authors wish to thank the other members of the AAR technical advisory team and the other members of the TTC staff who supported this project and provided assistance and hospitality during the fellowship program.

1.0 INTRODUCTION

In July, 1987 a Request for Proposal was issued by the United Nations Industrial Development Organization (UNIDO) to secure the services of a qualified contractor to provide assistance for the upgrade of the Diesel Locomotive Test Stand at the Dalian Diesel Locomotive Research Institute (DLRI), Peoples' Republic of China. The Association of American Railroads (AAR) responded with a proposal in early September 1987 and were awarded a contract in December 1987, at which time the planning work commenced on the project. This report describes the work carried out by the AAR in support of this contract from December 1987 until completion in September 1990.

2.0 BACKGROUND

The Dalian DLRI is one of the primary locomotive research establishments in the People's Republic of China (PRC). It was opened as a locomotive test facility in 1935 and has operated as a separate research institute since the early 1960's. As of January 1988, it had a staff off approximately 300 engineers and technicians, 150 skilled workers, and 100 management support workers. The Dalian DLRI has developed a wide range of test facilities to evaluate the performance of a number of locomotive components and systems, including radiators, hydraulic transmissions, traction motors, alternators, and other components.

In 1979 the Dalian DLRI commissioned a diesel locomotive test stand (dynamometer), which was designed and built by the institute staff. This test stand is one of only three of its type in the world. Of the other two, one is located at the Munich Test Center in the Federal Republic of Germany and the other at the AAR's Transportation Test Center (TTC) in the United States of America. Between 1979 and 1986, the Dalian DLRI test stand was used to measure the thermal performance and tractive effort of five locomotives, including the Dong Feng 4 locomotive which was manufactured at the adjacent locomotive factory. While the tests were generally successful, in that they provided data which enabled the manufacturers to improve the basic design of the locomotives, the conduct of the test was time consuming and the resultant data less accurate than desired.

In the past, the Dalian DLRI has received all of its assignments from the Ministry of Railways, and has carried out tests to support the development and design work of the Locomotive and Rolling Stock Corporation of the Ministry. Since 1985 however, the Dalian DLRI has been required to earn an increasing amount of its operating costs from contracts. Since 1990, it has received no direct financial support from the Ministry or any other government department, and now relies entirely on the income derived from contracts. In order to meet this challenge, it was deemed necessary to upgrade the efficiency and accuracy of the test stand. UNIDO agreed to fund the upgrade of the facility with matching funds being provided by the government of the PRC.

3.0 METHOD OF APPROACH

The original Request for Proposal [1] called for the Contractor to provide a complete turnkey system, meeting a full set of performance specifications. The performance specifications, which included measurement accuracy requirements and productivity improvement targets, were defined in Appendix 1 (titled, "Substantive Terms of Reference for Subcontract") of the Request for Proposal, hereinafter referred to as the "Terms of Reference". The original AAR proposal [2] offered two alternative approaches. The first alternative offered the services specified in the Request for Proposal. However, the estimated cost for this option exceeded the UNIDO funding target. Based on their direct operational experience of one of only three such facilities in the world, the AAR offered a second alternative. This alternative called for the AAR to provide the training and guidance for the Dalian DLRI test stand engineers to design, implement, and commission their own upgrade. Not only would this approach meet the UNIDO fiscal targets, it would also provide a sound technical base on which to build the future operation and maintenance support capability for the facility. In addition, the alternative approach would form a sound technical basis on which to expand the capabilities of the facility. The fellowship program, which was also an integral requirement of the Terms of Reference, was seen as the key to the success of this approach. This, coupled with a comprehensive assessment of the existing facility against the performance targets set out in the Terms of Reference were identified as the two vital tasks.

The fellowship program was designed to provide an environment which would allow the Dalian DLRI test stand engineering trainees to design the upgrades and specify the hardware under the direct supervision of the AAR key personnel. Where possible, the trainees would be given hands-on experience with hardware and testing techniques comparable with the goals of the Dalian DLRI test stand upgrade. Furthermore, the fellowship program was structured to train the computer engineers to develop their own software, using equipment comparable to that proposed for the upgrade. Given the vital role of the fellowship program in the project, an important part of facility assessment task became the evaluation of the existing skill levels of the Dalian DLRI test stand engineers. This was to ensure that the training provided during the fellowship program would develop the skill base necessary to successfully complete the upgrade program.

There were several advantages expected of the interactive method of approach to the project. First, it would make the maximum use of the available experience with the existing test stand. This would ensure that the best of the existing system would be retained, while the deficiencies would be accurately identified and remedied. Second, the involvement of the test stand engineers in the technical decision making process would promote added confidence in the success of the project. Third, this approach would greatly reduce the need for start-up training, since the test stand engineers would be gaining first hand experience of the new system during its development. At the outset, it was recognized that one of the main requirements for the success of this approach was the establishment of good communications among the main participants in the project (UNIDO, the Ministry of Railways, Dalian DLRI, the Chief Technical Advisor and the AAR).

A project implementation meeting was held at the TTC in late September 1987, between a joint delegation from UNIDO and Dalian DLRI and the AAR. After a very constructive meeting, a method of approach based on the second alternative, was adopted.

This was documented by the AAR in the form of a revised proposal [3], which was then submitted to UNIDO in October 1987.

4.0 CONTRACT MILESTONES

Following the successful adoption of the revised implementation plan, the AAR technical support effort was initiated. The major project milestones are listed and outlined below.

- **Final Contract** [4] - awarded - ***December 1987.***
- **Facility Assessment** - defined as Task I under the contract, this activity formed the technical basis for the upgrade (project scope definition and resource evaluation) - ***January 1988.***
- **Fellowship Program** - fulfilling portions of Tasks II and III, this activity provided training in instrumentation, computer, and testing technology (Task III) and initiated the upgrade design process (Task II) - ***February 1988 to December 1988.***
- **Site Missions** - covering the remaining portions of Tasks II and III and Tasks IV and V, the site missions were used to monitor progress, provide guidance to resolve difficult technical issues, continue the training process (particularly in software development) and provide continuous evaluation of final product.
  - **Final Design Review** - specifically to complete Task II, the purpose of this mission was to conduct a review of the final design and hardware selection - ***May 1989.***
  - **Control Software Implementation Review** - specifically to complete Task III, the main purpose of this mission was a review of the control software implementation on the upgraded computer system. Commissioning and demonstration activities, defined under Tasks IV and V, were also carried out - ***May 1990.***
  - **Computer Control Software Review and System Checkout** - the main purpose of this mission was to witness the initial checkout of the control software (the second phase of Task IV) and to observe the testing of a diesel hydraulic shunting locomotive (Task V) - ***August 1990.***
- The activities summarized here were coordinated thoroughly with the National

Program Director and the Chief Technical Advisor. In particular, the AAR site missions were planned to augment those undertaken by the Chief Technical Advisor and to respond to the specific needs of the program.

5.0 FACILITY ASSESSMENT

The first task specified under the contract was to send a mission team to the project site to conduct a complete assessment of the status of the facility and test hardware. Planning for this mission was greatly enhanced by a report [5] that had been received from the Chief Technical Advisor, who had visited the test stand in October 1987. He had assisted the test stand engineers in developing a preliminary list of transducers for the upgrade project and the selection of candidates for the fellowship program. In addition, some knowledge of the test stand had been obtained by the AAR team leader during an earlier visit in the summer of 1986. This also assisted the AAR team in preparing for the assessment task.

A full report [6] was prepared upon completion of the mission. A summary of that report is given below.

The AAR mission team arrived in Dalian on January 10, 1988 and departed on January 24, 1988. The objectives of the mission were a follows.

- To inspect the locomotive test stand and evaluate the existing capabilities of the test stand hardware.
- To conduct a review of the upgrade plan with the test stand personnel to ensure that the plan was sound and that the proposed equipment procurement list was complete and accurate.
- To assess the potential for future enhancements to the test stand in order that the utilization of the facility could be improved.
- To finalize the plan for the fellowship program that was to be conducted at the TTC during 1988, the main purpose of which was to complete the detailed design of the test stand upgrade.

An agenda was prepared by the National Program Director to ensure that the mission team could meet the stated objectives. The test stand engineers were available to participate in the technical discussions throughout the entire visit.

Three aspects of the upgrade project were given special attention as a result of recommendations made by the Chief Technical Advisor, following his visit to the DLRI in October, 1987. First, the instrumentation procurement list, which had been prepared by the test stand personnel and submitted to UNIDO, was reviewed for compatibility with the overall accuracy objectives of the upgrade plan. Second, the capabilities of the computer and measurement control system were reviewed to ensure that they would be able to perform the automatic control and data collection functions for the upgraded test stand. Third, the capabilities of the computer programming engineers was assessed to confirm that they possessed the necessary experience to develop the complex software required for this task.

Apart from the topics highlighted above, a study was made of the mechanical design and general layout of the test stand. In addition, the stability of the existing manual control system was assessed to determine whether computer control could be implemented without the addition of flywheels to the drive trains. A complete review was also made of the general instrumentation practices employed and the status of the existing measurement systems, including fuel consumption and tractive effort.

The main conclusions of the AAR mission team, based on their evaluation of the facility, are summarized below.

- The general location and mechanical layout of the locomotive test stand was one of its major attributes as a test facility; no improvements of the general test area were warranted. It was noted that the roll-on/roll-off loading capability was a particularly beneficial feature of the facility design.

- The mechanical elements of the drive trains were well designed and maintained in a good state of repair. No additions or modification were deemed necessary to support the basic function of locomotive performance testing.

- The test bay environmental control system (exhaust removal and ambient air temperature control) was of a sound design and was reported to perform satisfactorily.

- The field current-based inner control loop was found to be stable and suitable for use as the basis of a speed-based computer control system without the addition of flywheels to the drive train.

- Torque control of the drive trains for brake performance testing was deemed to be both desirable and necessary for the true simulation of vehicle inertia without flywheels.

- The load resistor bank switching contactors and control system would probably require some redesign prior to their conversion to automatic control.

- The decision to require both manual and computer control options to be retained after the upgrade would result in a major design effort to produce a reliable control mode switching and fail-safe interlock system. ***This requirement was later abandoned during the implementation phase of the project.***

- The existing fuel balance, with minor improvements, was to be retained as the prime fuel consumption measurement system after the upgrade.

- The torquemeters, which were currently installed in the drive trains, were inaccurate and susceptible to signal noise. These would have to be improved or replaced before torque control could be implemented.

- The pulse rate of the existing tachometers was marginal at speeds below 5 km/hr. Tachometers with a higher pulse rate, possibly incorporated in the new torquemeters, would be required before automatic speed control could be implemented.

- It was doubtful whether the coupler load could be used to make tractive effort measurements to the required $\pm 0.5\%$ accuracy level. To accomplish this level of accuracy, the position of the locomotive wheels with respect to the rollers would have to be maintained to within ± 0.5 mm. Engineering clearances, manufacturing tolerances, and structural deflections of the bogie frame members and locomotive body all combine to make accurate positional control difficult. High precision torquemeters would provide a more accurate measure of tractive effort.

- It was deemed that the general support instrumentation (pressure, flow, temperature, etc.) that had already been purchased, or was specified in the equipment list, would meet the requirements of the upgrade program. It was recommended that current and voltage should be measured using optically isolated shunts and voltage dividers.

- It was recommended that improved cabling and grounding techniques should be studied and incorporated in the upgrade design to ensure system reliability and accuracy.

- It was recommended that general purpose instrumentation and improved calibration and repair facilities must be included in any future plan to broaden the scope of test capabilities of the test stand.

- It was concluded that the existing Hewlett Packard A700 computer and HP 2250 Measurement and Control System had sufficient capability to handle the data collection and control requirements of the upgraded test stand. However, additional plug-in boards would be required to meet some of the additional tasks. ***It was subsequently found that additional boards were unavailable and the computer system was replaced.***

- The computer engineers assigned to the upgrade project had already gained experience in developing software for the HP system and had a clear understanding of the basic principles of the software design.

- It was concluded at that time, that the upgrade design task could be achieved within the time period of the fellowship program at the TTC, provided that careful coordination between the fellowship groups, and between each fellowship group and the National Program Director was adequately maintained. It was felt that this would best be provided by overlapping key personnel from the two fellowship groups, either at the TTC, or at the Institute before the departure of the second group. This was particularly true for the two sections of the computer software development team. ***It was subsequently decided that the software engineers would all be included in the first fellowship group.***

- It was reiterated that, for successful completion of the project, good communications be maintained among the test stand personnel, the AAR consultants, and the UNIDO Chief Technical Advisor during the installation and checkout phases of the project.

- It was found that there was ample potential for expanding the application of the test stand to other purposes beyond the performance testing of diesel electric locomotives. However, it was pointed out that the opportunity for such expansion could only come from establishing a market for these services, probably through the formation of a working relationship with other research organizations within the Chinese railway industry. Investment in equipment and expertise would also be necessary to accomplish this goal.

The results of the test stand assessment formed the basis for the subsequent implementation of the upgrade project. Some changes to the overall plan were found to be necessary as a result of hardware availability. In addition, some of the proposed system design features, such as the complex automatic to manual mode changeover circuitry, were abandoned during the detailed design phase of the project in the interest of cost and simplicity. The facility assessment mission was instrumental in determining the requirements for the training to be provided during the subsequent fellowship program, which was to play such a vital role in the success of the project.

6.0 PROJECT IMPLEMENTATION

6.1 Fellowship Program

The first step in the implementation of the DLRI test stand upgrade project was the fellowship program. As discussed earlier, the fellowship program was designed to provide the necessary insight and training in the use of advanced instrumentation techniques, computer-based control and data acquisition systems and testing methods. It was also intended that as much of the basic design work for the DLRI test stand upgrade as possible would be carried out so that the AAR team members would be available to provide the necessary assistance.

A total of eighteen engineers from the DLRI were selected for the fellowship program. They were divided into three groups according to their general areas of expertise and role in the upgrade project. The three general areas of study were:

- Instrumentation and Computer Systems.
- Electrical and Mechanical System Design.
- Testing Methodology Development.

This listing reflects the order in which the groups visited the TTC and the logical order in which the training was required to support the upgrade design process. While the above groupings represent the primary interests of the group members, where possible, the opportunity was provided for overlapping experience. For example, all fellowship trainees were provided with the opportunity to learn about the use of instrumentation and were also encouraged to use personal computers (PC's). While some of the fellowship time was spent studying documentation, much of the time was spent accompanying AAR technicians and engineers during their daily assignments. The latter was important to ensure that the theoretical knowledge was reinforced by sound practical experience. All remaining time available to the fellowship trainees was spent applying the knowledge gained to the DLRI test stand upgrade design.

Each group was responsible for producing a report to UNIDO, detailing the training received and the major accomplishments during the fellowship period [7,8,9]. However, for completeness, a summary of the activities of each group is given below.

Group 1 Instrumentation and Computer Systems - this group consisted of eight engineers (two instrumentation engineers, two mechanical engineers, one electrical engineer, and three computer engineers). They arrived at the TTC in February 1988 and departed in July 1988. As the group title implies, their main interest was instrumentation systems and computer data collection and control technology. The presence of the mechanical and electrical engineers in the group provided the balance of necessary expertise to progress the upgrade design.

The instrumentation engineers were trained in the selection process for measurement transducers, the setup procedures for signal conditioning systems and good instrumentation cabling procedures. They were also instructed in the procedures necessary to maintain calibration standards and in the collection and management of test data. Their main upgrade task during the fellowship was to complete the design and selection of the DLRI test stand instrumentation system. This task was successfully completed.

The computer engineers were instructed in the production techniques for the development of real-time process software. They were provided with the opportunity to program on the HP 9826 computers at the TTC. This was fortuitous, since the basic architecture of the HP 9826 was very similar to the HP 360 system, which was later used as the replacement for the HP 1000 (A700) system in the upgrade project. During their time at the TTC the computer engineers developed the functional specification for the control and data collection software [10]. This important document formed the basis for the subsequent software development.

The remaining members of Group 1 studied the mechanical layout and control system of the Roll Dynamics Unit (RDU). With their combined knowledge of the DLRI test stand and the RDU, they were able to produce an outline design for the test stand upgraded control system. By working closely with the computer engineers, a consistent approach to the eventual control scheme was assured.

Group 2 Electrical and Mechanical System Design - this group also consisted of eight engineers (two mechanical test engineers, three mechanical test equipment engineers, and two electrical engineers). They arrived at the TTC in July 1988 and departed in October 1988. As the group title implies, their main interest was in studying testing techniques, the design of test equipment (fixturing) and the electrical control system. Again, the presence of the mechanical and electrical engineers in the group provided the balance of necessary expertise to continue the upgrade design process. In order to facilitate this further, one of the computer engineers from the first group remained at the TTC for the first three weeks of the second group's fellowship. This provided some continuity in the upgrade design process.

The mechanical engineers in Group 2 generally worked together on the same assignments. They were provided with the opportunity to study the operation of the Rail Dynamics Laboratory (RDL), including the design and manufacturing of test fixturing for both the RDU and the Vibration Test Unit (VTU). They also observed numerous tests, both in the RDL and on the test tracks. While they were at the TTC, a test was conducted on a prototype locomotive equipped with an AC traction motor propulsion system, on the RDU. All the engineers in Group 2 participated in that test.

The electrical engineers conducted a complete evaluation of the RDU electrical control system. One of their major accomplishments was the development of an electrical system simulation model for the DLRI test stand control system. This model included realistic design parameters for the drive train motors. With some refinements, this tool was later used to great effect in the commissioning of the computerized control system.

Group 3 Testing Methodology Development - this group consisted of two mechanical engineers. They arrived at the TTC in October 1988 and departed in December 1988. During that time they were given the opportunity to study the TTC test methods in detail. They were briefed by TTC personnel on mathematical simulation validation testing, vehicle dynamics testing, and automatic control. They were not able to gain additional experience on the thermodynamic testing of locomotive diesel engines. In North America, this work is generally handled by the manufacturers or by specialized research laboratories. Diesel engine testing is not generally carried out at the TTC. The third group of engineers were, however, provided with the opportunity to study other test methods of use to them in the upgrade project.

6.2 Computer System Replacement

In September 1988 information was received that the additional circuit boards required to upgrade the HP 2250 Measurement and Control system to perform the test stand speed control and safety monitoring functions were no longer in production. It was also learned that technical support for this product by Hewlett Packard would be withdrawn at the end of 1988, followed shortly by the technical support for the HP 1000 series computers. A third party source for the additional circuit boards was identified, but the cost was found to be unacceptably high, particularly since the circuit boards would be supplied without acceptable warranty and after-sales support. After careful evaluation by the DLRI test stand engineers and consultation with the Chief Technical Advisor and the AAR advisors [11], the purchase of an alternative system was recommended to UNIDO [12].

An order for the replacement computer system was placed by UNIDO in March 1989, through the Vienna office of Hewlett Packard. The replacement system consisted of an HP 360 computer (one of the HP 300 series computers) and an HP 3852 Measurement and Control system. The test stand computer engineers were somewhat familiar with the HP 360 computer, since its architecture is similar to the HP 9826 computers that the test stand engineers had used at the TTC. They had also gained direct experience with the HP 360, since the AAR was, at the time, in the process of converting its data collection duties to the HP 300 series computers. The HP 3852, which itself incorporates an HP 300 series processor, is a much more powerful variant of the HP 6944 Multiprogrammer used by the TTC as the mainstay of its data collection capabilities. In order for the new system to adequately replace the original HP 1000/HP 2250 combination, the new software had to be written for the UNIX operating system. Consequently, the purchase order for the new computer equipment specified the UNIX operating system.

6.3 Design Review Mission

Following the successful completion of the fellowship program the detailed design of the test stand upgrade was completed by the test stand engineers. By the end of the first quarter of 1989 much of the instrumentation had been delivered and had been commissioned. In addition, the first version of the data collection and display software had been written for the HP 1000/HP 2250 system, pending delivery of the replacement system. A second AAR mission to the Dalian DLRI was arranged for the second quarter of 1989, scheduled to coincide with the testing of the Dong Feng 4B locomotive. A report [13] was prepared by the mission team upon their return. That report is summarized below.

The AAR mission team arrived in Dalian on May 14, 1989 and departed on May 28, 1989. The objectives of the mission were as follows.

- To observe the testing of a Dong Feng 4B locomotive on the locomotive test stand.
- To assess the progress made in implementing the improved measuring techniques into the test stand testing procedures.
- To review the final design of the test stand computer control system.
- To discuss the future plans for expanding the use of the locomotive test stand.

As with the previous mission, an agenda was prepared by the National Program Director. Ample time was made available for the two main objectives, namely, the review of the progress in implementing the new instrumentation and data collection techniques on the test stand and the final review of the test stand computer control system design.

The main observations and conclusions of the mission team are summarized below.

- The new instrumentation for monitoring the locomotive performance while on the test stand had been fully implemented. Initial indications were that the measurement accuracy and the quality of the data appeared to meet the objectives of the upgrade project. This assessment was later confirmed independently by the Chief Technical Advisor.

- Data collection and display using the existing computer system had been completed and had greatly speeded up the test procedure. A real time data display had been made available to the test stand operator on a monitor located adjacent to the control desk. The complete set of locomotive characteristic curves for each engine speed were plotted by computer at the end of each test sequence. Most of the newly developed software was capable of being translated and transferred to the new computer system when it became available.

- The new test procedures and data analysis techniques greatly reduced the time and effort required for testing.

- The software and hardware design for the computer control system were found to be satisfactory and ready for implementation. The report [10] describing the control software design had been finalized by the test stand computer engineers. This was later forwarded to UNIDO by the National Program Director.

- The list of computer equipment contained in the new computer system purchase order was reviewed and found to meet the requirements of the final design. It was recommended that an additional terminal be ordered for the HP 360 computer, which would greatly enhance testing efficiency.

- The delay in delivery of the new computer system was seen to have a direct bearing on the timely implementation of the computerized control system. ***During the meetings with the National Program Director the AAR mission team were informed of a possible delay in the delivery of the new computer system. This potential delay resulted from some of the items on the computer equipment list being on the COMCON restriction list and that approval had to be sought for their release. It was recommended that, if possible, delivery of the items not restricted by the COMCON review should be expedited so that the test stand engineers could start learning the UNIX operating system supplied with the new computer system.***

- Since the DLRI test stand engineers were not familiar with the UNIX operating system, it was recommended that Hewlett Packard be requested to provide a UNIX training course as part of the computer system procurement. This would not only assist the test stand engineers to develop the control software in a timely manner, but prepare them for future developments in the computer field. It is likely that UNIX will become one of the major standard operating systems used by the main computer suppliers for the foreseeable future.

- It was decided that, in order to expedite the development of the control system software, the development of the test stand control simulation program, started by

Group 2 during the fellowship program, would be completed. Tests to determine realistic values for the critical parameters of the test stand control system to be included in the model were recommended.

- The instrumentation list for the test stand control system implementation was found to be complete. All items had been delivered with the exception of the torquemeters, which were expected to be delivered by the end of August 1989.

- A draft standard for thermodynamic testing of locomotives to be supplied to the China Ministry of Railways by either domestic or overseas locomotive manufacturers was reviewed. Extensive enquiries had established that no international standard for this purpose currently existed. The draft standard being developed by the DLRI staff was subsequently offered to the Union Internationale des Chemin de fer (UIC) to form the basis of a new international standard.

- The techniques and experience gained during the fellowship program were evident in the progress of the project. The experience gained in computer software preparation was well demonstrated. For example, the new software developed for the HP 1000 computer used FLEX, a highly structured form of Fortran, which the DLRI computer engineers had learned at the TTC. The instrumentation installation and calibration techniques also employed knowledge gained during the TTC training. The diligent use of shielded cables for the transducer systems was strong evidence of this.

It was generally concluded that the project was progressing smoothly towards a timely completion. The only potential major obstacle to this process was seen to be the prolonged delay in the delivery of the new computer system.

Following the recommendations made in the mission report, UNIX training was provided by Hewlett Packard as part of the equipment purchase. In addition, the AAR contract was extended to provide additional support at the DLRI during the software preparation and commissioning.

6.4 Control Software Implementation Progress Report

Steady progress was made on the instrumentation installation, following the AAR's May 1989 mission. Only the development of the computer control software was impeded, due to the late delivery of the HP 360/HP 3852 computer system. Some delay was also experienced in the delivery of the torquemeters, but this did not significantly affect the overall progress, since the computer system was the critical item. To partly offset the delays caused by the unplanned replacement of the computer system, work continued on the development of the data collection software using the HP 1000 computer system. The contingency plan was that this software would be later transferred to the HP 360 computer.

The HP 360 computer system was delivered and commissioned in December 1989. After receiving training from Hewlett Packard personnel in Beijing (on UNIX for the HP 360 computer) and Dalian (for the HP 3852), the DLRI computer engineers began the control software preparation. By the end of April, 1990, the DLRI engineers were at a stage in the project where on-site assistance from the AAR was required. Consequently, an AAR mission was arranged for the second quarter of 1990. A mission report [14] was prepared by the mission team, the main points of which are summarized below.

The AAR mission team arrived in Dalian on May 13, 1990 and departed on May 25, 1990. The objectives of the mission were as follows.

- To review the new HP 360/3852 computer system hardware to ensure that the system was complete and would meet the test stand control and data collection system requirements.
- To provide technical assistance in the implementation of the UNIX operating system and the integration of the HP 360 computer with the HP 3852 Measurement and Control system.
- To assess the progress made in implementing the control system software.
- To continue the discussions of the plans for expanding the use of the locomotive test stand.

As was the usual practice, an agenda for the mission was prepared by the National Program Director. The major emphasis was placed on meeting the first three objectives. The AAR computer advisor worked almost exclusively with the test stand computer engineers investigating interface problems between the UNIX operating system and the HP 3852 software, establishing communication with the individual hardware modules and developing the main elements of the computer control system. After a careful review of progress and assessment of the outstanding tasks to completion, a revised schedule was proposed. Meanwhile, the AAR team leader discussed the plans for expanding the use of the test stand in detail, with special emphasis on the installation of an electro-hydraulic shaker system to perform bogie suspension characterization and locomotive modal analysis.

The main observations and conclusions of the mission team are summarized below.

Project Status

- The HP 360/3852 equipment was delivered and installed by December 1989.
- Training on the UNIX operating system was provided by Hewlett Packard in Beijing in January 1990 (two levels of training provided to three people).
- Training on the use of the HP 3852 was provided by Hewlett Packard at the Dalian Diesel Locomotive Research Institute during April 1990 (seven people). The training concentrated on the data collection system only. No training was available on the control features of the HP 3852, hence the need for AAR assistance at this time.
- During initial checkout it was discovered that the version of the DACQ (the HP 3852 access software) supplied with the DLRI system did not interface with the UNIX operating system. It was later determined that Hewlett Packard had already corrected the problem after delivery of the DLRI system and that new versions of the software were available.
- No service agreement was purchased with the system due to delivery being made from US. It was recommended that UNIDO purchase a local service agreement with the Beijing office of HP for a period of one year.
- Several major program modules, which are indicated below, were written and checked out during the mission, using the Rocky Mountain Basic computer language. These modules were designed to commence the integratation of the HP 360 computer and the HP 3852 as a data collection system. As a temporary measure, until the upgraded UNIX could be installed, these program modules were checked out in their uncompiled format. All of the items would later be compiled to operate under UNIX.
    - The display of data on the second monitor was successfully initiated.
    - The data multiplexer was successfully accessed under Rocky Mountain Basic.
    - The speed pulse counter boards were successfully operated.

- The A/D converter system (digitizer) was triggered to scan data.
- A fundamental program was developed whose structure was later to form the basis of the future control and data acquisition systems.
- The checkout of the test stand control simulator program was completed.

- The design of the electronic interface between the computer system and the test stand control system had been completed. The installation was scheduled to be carried out in July 1990.

- All remaining instrumentation hardware had been ordered by UNIDO. Most of the items were scheduled for delivery by the end of July 1990. The delivery schedule for the rest of the equipment (the digital oscilloscope, the signal generator, and the pulse generator) had not been established at that time.

Revised Schedule

- An interim solution, in which the HP 360/3852 would control the test stand and the HP 1000/2250 would collect and analyze the data, was to be implemented by August 1990.

- A test on a Diesel Hydraulic shunting locomotive was planned to be carried out in early August 1990.

- Final completion, in which the HP 360/3852 was to perform all functions (control, data collection, and analysis) would be accomplished by November 1990.

- It was recommended by the DLRI staff that the Tripartite meeting be held in Dalian at the end of November 1990 to witness the completion of the project.

Phase 2 Proposals

- It was recommended that the test stand control software be expanded to permit torque control of the rollers for braking tests and duty cycle simulation.

- It was concluded that a two actuator system for modal analysis and bogie suspension parameter identification could easily be installed in the test stand. Preliminary design parameters for such a system are:

  Actuator Force - 100 to 150 KN
  Actuator Stroke - 200 mm
  Servovalve Size - 250 l/min (90 gpm)
  Power Supply - 400 l/min (120 gpm) at 21 Bar (3000 psi)

- Other suggestions for Phase 2 included:

  - The development of procedures for the use of the test stand as a locomotive simulator for driver training.

  - The development of techniques for locomotive microprocessor checkout on the test stand.

  - The development of computerized duty cycle inputs for service simulations (cooling system evaluation, etc.).

General Recommendations

- Hewlett Packard be requested to supply, as appropriate, new versions of UNIX, the DACQ software, and Rocky Mountain Basic, at no extra charge to either UNIDO or the Dalian DLRI. This request was to be made on the grounds that HP should have known that the problem existed before they sold the system to UNIDO.

- The sample rate for data collection be increased to help in signal noise mitigation.

- The existing data analysis programs, which were originally installed on the HP 1000, be transferred to run under UNIX on the HP 360 with minimal changes. If possible, data formats on the HP 360 and HP 1000 computer systems be made compatible.

- A stand-alone Basic compiler (IEM) be purchased to speed up software execution times.

While the AAR mission team was visiting the DLRI, it was learned that the test stand instrumentation engineers had been awarded a contract by the Ministry of Railways to provide instrumentation support during a service test of a heavy haul freight train. During this test the DLRI engineers successfully applied the techniques that they had learned at the TTC, using some of the instrumentation that had been purchased as part of the test stand upgrade project. The fact that they were successful in this venture was a clear indication that the secondary objective of the project, namely that of expanding the business base of the DLRI, was already being pursued. The fact that the test stand engineers were able to competently handle such a task at this stage in the upgrade project showed much promise for the successful completion of the project.

6.5 Computer Control Software Review and System Checkout

At the end of the third mission, the DLRI engineers were well on the way to completing the final phase of the software development, including the roller speed control software modules. However, completion of the task for an August 1990 demonstration was a very optimistic target. An international conference on diesel locomotives was scheduled to be held at the Dalian DLRI on August 7 -10, 1990, during which the test stand was to be featured as one of the exhibits. The fourth and final AAR mission to the DLRI was scheduled to coincide with this conference. The details of the mission are presented in the final mission report [15], a summary of which is presented below.

The AAR mission team arrived in Dalian on August 2, 1990 and departed on August 17, 1990. The objectives of the mission were as follows.

- To assess the progress made in implementing and commissioning the computer control system.
- To provide assistance in the commissioning process where necessary.
- To define the tasks necessary for the completion of the current phase of the project.
- To assess the overall success of the project in meeting the upgraded performance targets.

<u>Accomplishments</u>

The main emphasis was placed on providing assistance in commissioning the control system software. The bulk of the preparation work had been completed by the test stand engineers before the arrival of the AAR mission team. However, some refinement and fine tuning was jointly carried out as follows.

- The HP 3852 control software was modified to allow continuous data acquisition.
- Additional tabular data displays were developed to permit real-time monitoring of the test stand status.
- The software code was streamlined into a workable form to produce an acceptable

major cycle time (control iteration step).

- The test stand simulator (the test stand simulation model developed during the fellowship) and the control programs were modified to allow them to interact realistically within the major cycle time.
- Graphic displays were incorporated into the control program for troubleshooting system errors.
- Feedback parameter (PID) sensitivity analyses were performed on the computer control loop of the test stand control system.
- The ability of the control system software to control the test stand with a diesel hydraulic locomotive was demonstrated.

<u>Short-term Improvements</u>

When the AAR mission team departed from the DLRI, the plan was to use the diesel hydraulic locomotive test as the final checkout for the computer control system. A diesel hydraulic locomotive is not an ideal test specimen for evaluating the effectiveness of the computerized roller module speed control, since the driven axles are effectively tied together by the transmission system. Therefore, only the speed of one module can be controlled by computer, while the tractive effort of other modules is controlled by matching their field currents to the computer controlled module. However, the diesel hydraulic locomotive represented the only opportunity to check the system out in the relatively near future. Some preliminary testing on the diesel hydraulic locomotive was carried out during the AAR mission, which showed that a meaningful interim checkout could be performed.

In order to proceed with the use of the computer control system for the subsequent diesel hydraulic locomotive test, the following short-term refinements were recommended for implementation.

- Control system measurements (armature current and voltage, field current and voltage) should be provided to the HP 3852 to allow safety checks to be made and analysis of the system behavior to take place.
- Baseline test measurements (drive train torques and the remaining speed channels) should be incorporated into the HP 3852 to monitor test performance.

- Fundamental safety checks and alarm responses should be defined, incorporated, and tested.

- Final optimization of the control system (PID) parameters should be carried out for the full range of the diesel hydraulic locomotive speeds and power levels.

- A display terminal should be provided at the test stand control desk for the operator (with limited display capabilities if necessary).

- The inter-axle armature voltage multiplication factors should be refined to provide a more precise torque balance among the rollers for diesel hydraulic locomotive testing.

Long-term Improvements

The following steps were recommended to complete the software project, as specified under Phase 1 of the Test Stand Upgrade Program.

- The control logic should be consolidated to minimize the program size and to allow for more flexibility and maintainability.

- A simple locomotive control model should be incorporated into the test stand simulator to allow a more realistic response for power level changes.

- The safety checks, alarm requirements, and interlock schemes should be consolidated and fully integrated into the control software.

- Individual axle speed control of the test stand (essential for diesel electric locomotive testing) must be incorporated into the control software.

- The data analysis routines should be transferred from the HP 1000 computer to the HP 360 computer and the analysis system input routines modified to read the HP 360 computer data format.

- The HP 360 computer data acquisition and control (DAC) program should be modified to carry out fuel consumption measurement.

- Facilities for the collection of low sample rate data (such as temperature) should be incorporated into the DAC program.

- A user's guide and a programmers manual should be prepared for the completed DAC software, and cross-training should be provided to the other test stand computer engineers. This will permit greater flexibility for future upgrade and maintenance support.

Instrumentation

The following instrumentation tasks were recommended in order that the first phase of the test stand upgrade project can be considered complete.

- The universal patch panel installation should be completed.
- The roller drive train losses should be measured so that corrections can be applied to the torquemeter readings to give accurate tractive effort measurements.
- Control system measurements (armature current and voltage, field current and voltage) should be installed to the patch panel to allow the HP 3852 to perform safety checks.

This mission was the last to be carried out by the AAR under the provisions of Phase 1 of the test stand upgrade project. It was concluded at the end of the mission that, once the outstanding tasks outlined above had been completed, all the objectives of the current phase of the project would have been successfully met.

6.6 Accuracy Assessment

One of the recommendations made at the end of the final AAR mission was that a complete accuracy assessment be carried out at the first available opportunity. Ideally, this would be conducted in conjunction with the first test on a diesel electric locomotive, since this would provide an opportunity to examine the complete instrumentation and control system. Preliminary checks of the torquemeters during the final mission indicated that their accuracy and stability were excellent. However, since these devices provide the baseline measurements of locomotive performance, special attention should be paid to them during the accuracy assessment.

When the AAR mission team left the DLRI a test on a diesel electric locomotive was scheduled for the test stand within the year, using the fully upgraded system. It was suggested that a full audit of the system could be performed in conjunction with that test. The AAR technical advisors expressed their willingness to participated in such an audit by performing an independent analysis and cross-correlation of the test data, without the need for an additional mission. Although no indication has been received to date that suitable data is available. the offer to participate in the audit still stands.

7.0 DISCUSSION

7.1 Test Stand Upgrade Program Status

Phase 1 of the locomotive test stand upgrade project has been successfully completed. The speed of the test stand rollers is now under full computer control, a new instrumentation system has been specified and installed, and the data is collected and displayed by computer. The benefits of these achievements have already been demonstrated in the form of increased productivity resulting from more rapid testing with fewer manhours. In addition, the test stand is now operated and maintained by a group of well trained and dedicated engineers, who are fully aware of the capabilities and future potential of the new facility. They have already demonstrated their ability to apply their newly acquired instrumentation and computer expertise to other areas of railway testing. One of the problems that now face the test stand administration is the possibility of the the loss of the newly acquired expertise through the transfer of personnel before the upgrade project is fully consolidated. As the engineers move on to other assignments. the detailed knowledge of the test stand upgrade may be lost unless the system is fully documented. The documents must include design and maintenance manuals for both the instrumentation and computer system hardware. In addition, the computer software must be fully documented for the future.

Most of the upgrades recommended for Phase 2 are well within the capabilities of the test stand engineering staff to accomplish with minimum outside assistance. One of the proposed Phase 2 recommendations, namely, the implementation of computer torque control of the rollers for braking tests, is essential for the long term future. The test stand engineers have demonstrated their ability to successfully perform this task. The prospects are good for a successful completion of an enhancement program, to whatever level is deemed necessary for the maximum benefit to the railway system of the Peoples' Republic of China.

7.2 Review of Upgraded System Against Original Objectives

The original objectives required that the measurement accuracies be significantly improved, to meet a general accuracy target of better than 1%. The targets for certain key measurements were even tighter. For example, the specified accuracy for tractive effort measurement was 0.5%, while the accuracy requirement for the fuel measurement was specified at 0.3%. The transducers, signal conditioning and data collection systems were selected on the basis of the accuracy targets. From all indications, it can be concluded that the accuracy targets have been met. This conclusion was reached by the test stand engineers and by the Chief Technical Advisor in their respective final reports [16, 17]. The continued maintenance of the equipment, including routine calibration of the transducers and measurement systems, is crucial to perpetuate data accuracy. The knowledge and experience gained by the test stand engineers as part of this project should ensure that the current high standards of accuracy are maintained and even enhanced.

With regards to the target of improving the overall productivity of the test stand, this has already been well demonstrated by the routine test programs that were conducted during this project. In their final reports [16, 17], the DLRI test stand engineers and the Chief Technical Advisor independently stated that the testing time had been reduced from three to four months duration to four to six weeks. The test stand engineers also reported that the test staff had been reduced from twenty to fifteen, a staff reduction of 25%. Not mentioned in either of the final reports is that the processed data can be made available to the locomotive designer during the test so that real-time decisions can be made on the accuracy of the data, the locomotive performance and the need for additional data points. This is a very important benefit to the test director in optimizing the test program. A further benefit resulting from the computerized data processing and reduction is the potential for issuing the test report soon after the test is complete.

One of the objectives, which has not been fully met, is for the testing to be conducted against acceptable international standards. This subject will be more fully addressed in Section 7.3. As will be seen from the subsequent discussion, the reasons for not meeting this objective were beyond the ability of any of the participants in the DLRI upgrade program to control.

The final objective to be addressed in this discussion concerns the intent of the program to provide the test stand engineers with experience and skills that can be utilized for supporting the test stand and expanding its role in the future. It is a pleasure to be able to report that this objective has been fully met. The fellowship program provided the basis for this success. However, it was the hard work and dedication of the test stand engineers themselves that allowed them to take full advantage of the training being offered. Their skill levels and knowledge was readily apparent throughout the conduct of this phase of the upgrade program. That skill base is now available to support not only further upgrades of the DLRI test facilities, but expand the role of the DLRI within the railway industry of the Peoples' Republic of China.

7.3 International Testing Standards

As stated earlier, one of the original objectives was to establish the testing methods on the DLRI test stand in accordance with accepted international standards. However, it quickly became clear that standards for the complete thermodynamic and traction performance evaluation of a locomotive, either on a dynamometer or during a track test, did not exist. Both the UIC and the AAR have standards for diesel engine testing. The AAR also adopts standard testing procedures for tractive performance testing of locomotives [18]. Despite the best efforts of the Chief Technical Advisor [11], no reference to a suitable standard could be located.

In the absence of an existing standard, a draft standard was developed by the DLRI test stand engineers [19]. This has been submitted to the Ministry of Railways of the

Peoples' Republic of China for adoption as an acceptance procedure for both foreign and domestically produced locomotives. It has also been submitted to the UIC to form the basis of a UIC sponsored international standard. Decisions on both of these submittals are still pending. In this respect, the DLRI test stand engineers have used their skill and knowledge to make a technical contribution to the international railway community.

7.4 Prospects for an Expanded Role for the DLRI

Part of this discussion has already examined the prospects for the success of further upgrades to the DLRI test stand, based on the developing skill levels of the engineers and equipment procurements resulting from the accomplishments so far. However, the success of this project has the potential for further benefit, both in support of China's railway industry and in support of the local enterprises in Dalian. There are three main avenues for an expanded role that should be explored. These are:

- Instrumentation and data collection services for testing on the railways.
- General instrumentation, calibration, and data collection support for local companies.
- Computer software and hardware applications (both for the Ministry of Railways supported projects and for local enterprises in Dalian).

The test stand engineers have already demonstrated their ability to support railway service testing by completing a heavy haul traction performance test in June 1990. The expanded use of their skilis to other projects will be a very positive step in ensuring the long term viability of the DLRI.

7.5 Success of the Method of Approach

The successful completion of this project on time and within budget was accomplished for a number of reasons. Lessons may be learned from this project that can be successfully applied to future projects. An analysis of the method of approach is therefore relevant for that purpose. The reasons for the success of this phase of test stand upgrade project can be summarized as follows.

- A clear definition of the objectives for the upgrade had been established by the Ministry of Railways and the Dalian DLRI staff before the submittal of the proposal to UNIDO.

- All participants in the project (UNIDO, the Ministry of Railways, the DLRI National Program Director and the test stand engineers, the Chief Technical Advisor and the AAR technical advisors) shared the common interest of efficiently completing the project.

- The technical support functions (the Chief Technical Advisor and the AAR technical advisors) were experienced, not only in the techniques and equipment that were being applied to the project, but also in the role that the upgraded facility was to play.

- Good communication and working relationships were maintained throughout the project implementation. The project implementation was conducted in the atmosphere of a partnership rather than the conventional supplier/customer relationship.

- A careful assessment of the existing hardware and of the expertise of the facility support personnel was carried out before the upgrade plan was developed.

- The implementation plan first established a firm technical base on which to build the subsequent upgrade through sound technical training (the fellowship program).

- The future custodians of the facility were encouraged to design and implement their own upgrade plan, including the specification, procurement, installation and commissioning of the hardware, and the development of the software. Thus, they were primarily responsible for all of the decision making that would affect the future viability of the facility.

- The project was built on the skills and expertise of a dedicated and enthusiastic group of engineers and project leaders, who clearly understood the project objectives and took pride in its success.

It is recognized that it is not always possible to duplicate the unique characteristics of this project in technical assistance programs. However, when they do occur, the chances of success for the project are surely greatly improved.

8.0 CONCLUSIONS

Two sets of conclusions are offered regarding the status of the DLRI test stand upgrade project. First, directly addressing the conduct and status of Phase 1 of the project, the AAR advisors conclude that:

- The first phase of the Dalian DLRI upgrade project was completed on schedule and within budget.
- The measurement accuracy targets (better than 1% for general measurements and better than 0.5% for critical measurements), defined in the project objectives, have been met.
- The testing time for the complete thermodynamic and performance of a diesel electric locomotive has been reduced from three to four months to four to six weeks.
- The test team required to conduct a locomotive test has been reduced by 25% (from twenty to fifteen).
- The successful completion of this project resulted from the implementation of a well developed plan, with clearly defined objectives, carried out by a team of enthusiastic and dedicated engineers, coordinated by good project leadership.

With regards to the prospects for future enhancements to the DLRI test stand, it is the opinion of the AAR technical advisors that:

- Opportunities exist for expanding the role of the DLRI test stand in support of the Ministry of Railways locomotive research programs. In addition, the computer and instrumentation expertise, developed as a result of this project can benefit other research programs sponsored by the Ministry of Railways and in support of the local engineering enterprises.

9.0 RECOMMENDATIONS

In order to consolidate the accomplishments of phase 1 and to provide expansion capabilities for the future, the AAR technical advisors recommend that consideration be given to the following actions:

- The project documentation, including the software manuals, the test stand maintenance procedures and the instrumentation installation and calibration manuals should be completed to avoid the loss of vital information.

- When the opportunity arises, a complete audit of measurement and data processing accuracy should be carried out, using the set up procedures and test data from a full diesel electric locomotive test.

- The additional upgrades proposed as Phase 2 of the program, including the installation of a suspension characterization and modal analysis electro-hydraulic shaker system, should be considered to enhance the capabilities of the Dalian DLRI to support the testing of locomotives.

- The role of the Dalian DLRI test engineering expertise should be expanded to further support the Ministry of Railways research program and the testing needs of the local engineering enterprises.

- When possible, international technology transfer projects should be designed to build upon a base of existing technical expertise. If necessary, the required technical training should be provided before hardware is committed to the project.

10.0 REFERENCES

1. S. Morozov, "UNIDO Project DP/CPR/85/019 - Improvement on Locomotive Test Stand, Dalian", Request for Proposal P87/37, July 1987.

2. D. A. Watts et al, "Improvement on Locomotive Test Stand, Dalian", AAR Proposal P87/37 - UNIDO Project DP/CPR/85/019 (Ref: MKTG/DAW/87-147), September 1987.

3. D. A. Watts et al, "Improvement on Locomotive Test Stand, Dalian", AAR Proposal P87/37 - UNIDO Project DP/CPR/85/019 (Revised), November 1987.

4. D. Gardellin, "UNIDO Project DP/CPR/85/019 - Improvement on Locomotive Test Stand, Dalian, Peoples' Republic of China", UNIDO Contract No 87/135, February 1988.

5. Dr W. J. Harris "Report to UNIDO", Progress Report, November 1987

6. A. J. Peters, M. A. Dembosky, W. N. Cooksey, "Assessment Report - Dalian Diesel Locomotive Research Institute Test Stand Upgrade Program", AAR Report to UNIDO, January 1988.

7. Li Dunkang, Gu Maoliang, Han Deguan, Ling Changyin, Wen Quan, Liu LiLi, Fan Yin, Chen Yiqing, "Final Report of the First Group at TTC", Fellowship Report to UNIDO, August 1988.

8. Feng Jincai, Bi Shude, Zhou Yirou, Zhang Chongtang, He Yongjun, Xu Chengyue, Man Changzhong, Lu Guoying, "The Second Group Training Report", Fellowship Report to UNIDO, January 1989.

9. Tang Qiyuan, Fu Shiyuan, "The Third Group Training Report", Fellowship Report to UNIDO, April 1989.

10. Chen Yi Qing, Fan Ying, "The Outline of Dalian Test Stand Computer Software System", Dalian DLRI report to UNIDO, July 1988.

11. Dr W. J. Harris, "Report on the UNIDO Project to Upgrade the Locomotive Test Stand", Chief Technical Advisor Report to UNIDO, October 1988.

12. Dr W, J. Harris "Computer Requirements for the Locomotive Test Stand Upgrade at the Dalian DLRI", Memorandum to Dr H Seidel, October 1988.

13. A. J. Peters, M. A. Dembosky, "Design Review Progress Report", AAR Report to UNIDO, January 1990.

14. A. J. Peters, M. A. Dembosky, "Control Software Implementation Progress Report", AAR Report to UNIDO, July 1990.

15. A. J. Peters, M. A. Dembosky, "Final Inspection Progress Report", AAR Report to UNIDO, September 1990.

16. Dalian DLRI Staff, "Improvement on Dalian Locomotive Test Stand - DP/CPR/85-019", Final Report to UNIDO, October 1990.

17. Dr W. J. Harris, "Comments on the DLRI Locomotive Test Stand Upgrade", Attachment A of DLRI Final Report to UNIDO, September 1990.

18. W. M. Scott, R. B. Skene, B. A. Biglow, "Locomotive Traction Performance Measurement", American Society of Mechanical Engineers (ASME) Paper No. 75-RT-8, April 1975.

19. Chen Chougui et al, "Test Stand Methods for the Testing of Diesel Locomotives of the Tractive Effort and Thermodynamic Performance, Draft Test Standard, April 1989.